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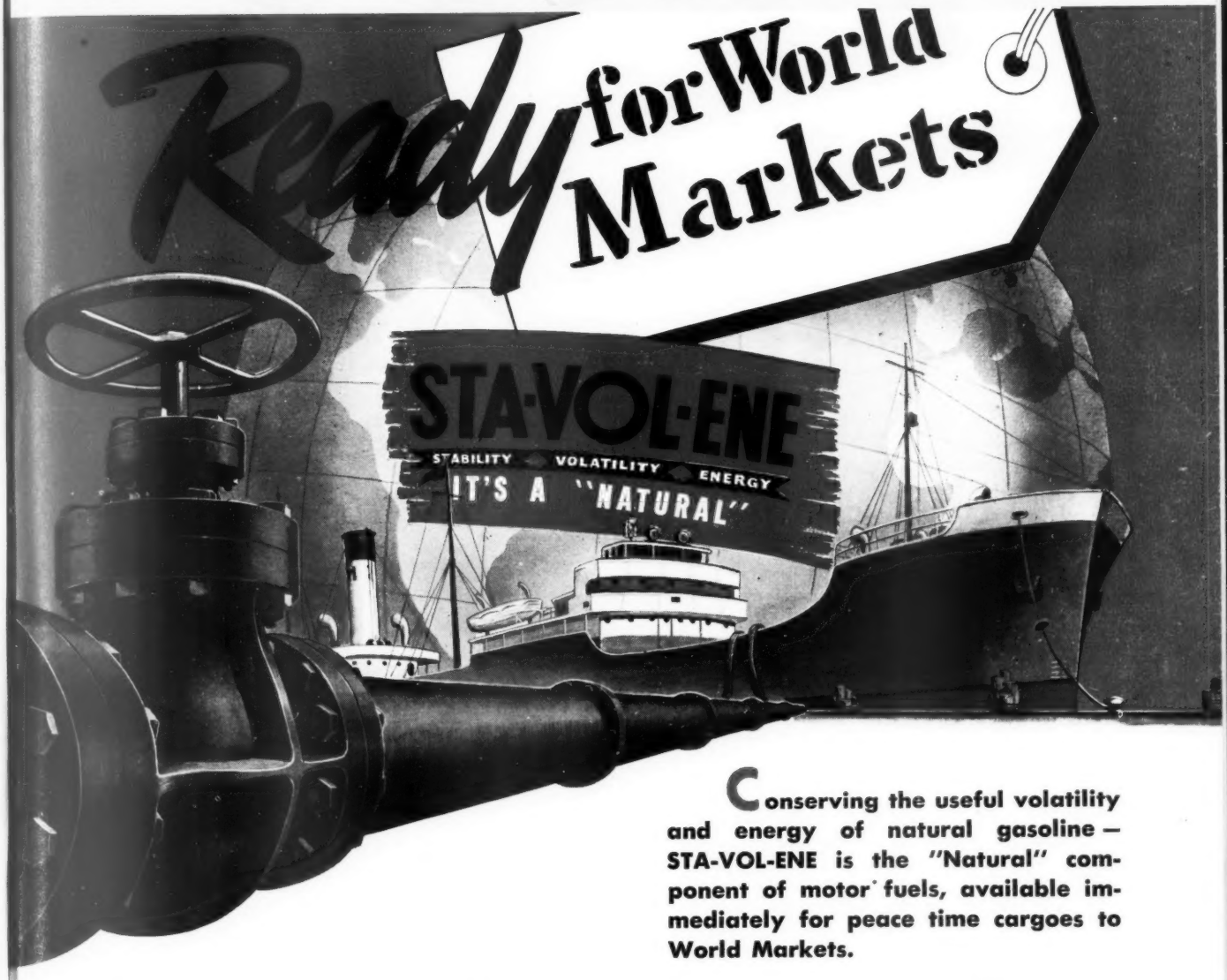

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published weekly by the

PETROLEUM PUBLISHING COMPANY

211 S. CHEYENNE AVE., TULSA 1, OKLAHOMA

FOUNDED IN 1910 BY PATRICK C. BOYLE

Subscription rate to the petroleum industry, United States and foreign, 1 year, $3.00. Single copies, 20 cents. Back copies, when over a year old, 50 cents. Note: Payments from outside the U. S. A. may be in the form of an international money order or check on a U. S. A. bank. Entered as second-class mail matter at Tulsa, Okla., under Act of March 3, 1879.

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Vol. 44, No. 47 March 30, 1946

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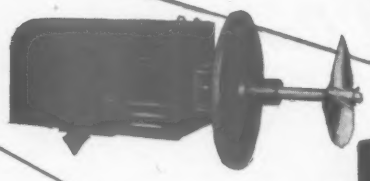

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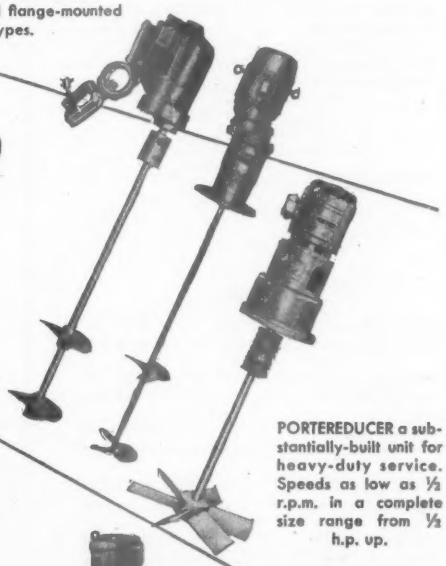

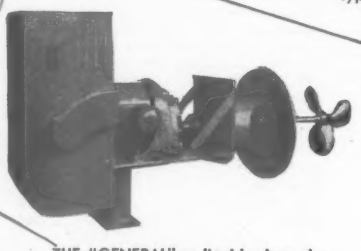

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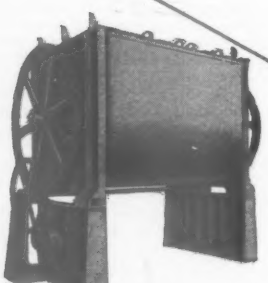

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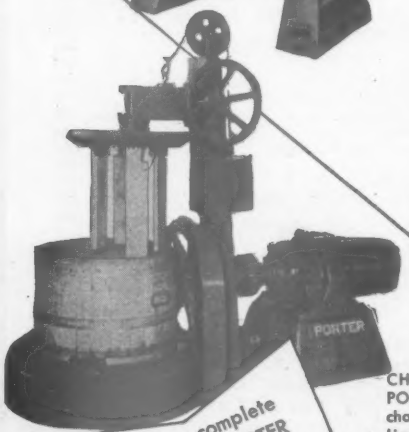

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THE OIL AND GAS JOURNAL

We Catalyze

OPERATORS, regardless of their particular niche in the petroleum industry, can well afford to make whatever studies are required to obtain a comprehensive appreciation of the technical and economic data of this Annual Refining Number. Without attempting to oversimplify something which is not simple, the Journal editors, with the aid of builders and operators, have presented an understandable description of postwar trends in the manufacturing phases of this industry's operations.

Outstanding is the fact that today's new refinery arts center in the application of catalysis to plant operations. The primary distillation operations on which the refining industry was founded, continue unchanged except for further refinements and increased operating efficiency. The several applications of catalysis have brought forth new products and improved the quality of existing products.

A few years ago it was thought by many that refineries were nearing the maximum in gasoline yields through the application of high-temperature and high-pressure cracking of intermediate and residual fractions of a barrel of crude oil. But this tool of catalysis, which has important uses in other industries, now makes commercially possible a decomposition of the heavier fractions into lighter components along the entire refining front.

Catalytic cracking and all the associated operations which were so quickly expanded during the war period are more than gasoline producers. It is true that during the war they were utilized to refine those hydrocarbons required in the blending of the highest-octane gasoline. Since the war's end most of these operations have been adapted to the production of superior grades of motor fuels with greater facility than was thought possible a year to 3 years ago.

But the economist wants to know what the end results of this acceleration and broadening of distillation will be a year or 10 years from now. With the industry running its own business, including price relationships, it will mean several things.

Improvement in quality and quantity of products in catalytic operations does not stop with gasoline but includes all overhead products. Properties of crude oil will be of decreasing importance. The operating flexibility is such that reasonable price variations to take care of seasonal conditions will assure that all the many demands for petroleum will be met everywhere. Catalysis is also the base on which a new petrochemical industry rests.

So we definitely know that petroleum's manufacturers have a new tool the potentialities of which are just beginning to be understood and applied. Its over-all industrial significance is certain to be among the half-dozen major developments in oil history.

O'Mahoney Report May Shape Oil Policy for Years Ahead

by Henry D. Ralph

WASHINGTON. — The year-long study of the world's oil industry by the Senate committee on petroleum resources draws to a close this week when a few "cleanup" witnesses are scheduled to present additional data on several of the many subjects which have been covered in the various series of hearings which began last spring.

With all hearings officially closed the committee will begin the work of writing its report, which will be chiefly the views of Chairman Joseph C. O'Mahoney of Wyoming who was the only member sitting through all, or even many, of the hearings. In theory this report will become the basis for the Government's oil policy and the guide to future legislation.

In view of this it is significant that the final series of hearings, devoted entirely to problems of the independent oil man, produced no requests for reform of the industry, novel legislation, nor special government aid.

There were suggestions, but not a unified demand, that some form of price inducement may have to be devised if the Government considers it sufficiently important to the national welfare to recover the oil reserves remaining in stripper-well fields and secondary-recovery projects.

There were also requests for protection against excessive imports of foreign oil, for a sound and fair tax policy, for easier access to oil on the public domain, and for continued government research on technical problems of secondary recovery.

Beyond that the independent oil companies asked only that the federal Government let them and the oil-producing states work out their own future salvation, and they promised that this would guarantee that the nation would always have an adequate supply of oil at reasonable prices.

Throughout the hearings the oil industry presented a practically unanimous viewpoint on all important subjects, and there was no evidence of bitter warfare, or even much divergence of opinion, between major and independent operators. Majors were mentioned only casually, and Chairman O'Mahoney had to call on the Department of Justice for evidence to support his view that the concentration of economic power is increasing.

W. B. Watson Snyder of the anti-trust division read into the record the tabulation of a survey recently made in the course of the Justice Department's studies which did show that in most activities in the industry the big companies have enhanced their relative position during the war, as follows:

Five-Year Changes

Number of producing wells—21 companies owned 27.6 per cent in 1939, 29.4 per cent in 1944.

Gross production—21 companies had 52.2 per cent in 1939, 61.3 per cent in 1944.

Stocks of crude—19 companies had 75.5 per cent in 1939, 78.9 per cent in 1944.

Crude runs to stills—19 companies had 80.9 per cent in 1939, 83.2 per cent in 1944.

Motor fuel manufactured—19 companies had 72.6 per cent in 1939, 64.6 per cent in 1944.

Stocks of motor fuel—19 companies had 80.4 per cent in 1939, 56.8 per cent in 1944.

Aviation gasoline manufactured—17 companies had 56.9 per cent in 1939, 73.8 per cent in 1944.

Crude-refining capacity—21 companies had 75.8 per cent in 1940, 82.0 per cent in 1945.

Cracking capacity—21 companies had 84.1 per cent in 1940, 85.8 per cent in 1945.

SEN. JOSEPH C. O'MAHONEY

Catalytic-cracking capacity—18 companies had 100 per cent in 1940, 88.2 per cent in 1945.

On the subject of preserving competition and preventing monopoly, the oil-industry witnesses appeared to consider the major companies less of a threat than the recent rapid growth of the cooperative movement. Farm co-ops, they declared, are rapidly expanding into all branches of the petroleum business, buying out established concerns at high prices. The explanation is that co-ops pay no income taxes and need not distribute their earnings to stockholders so they have been able to accumulate large sources of capital for expansion. The oil men asked that the Government either confine co-ops to the business of marketing farm products or subject them to the same taxes as orthodox forms of business activity.

The issue of major versus independent was discussed by Fayette B. Dow, counsel for the National Petroleum Association, who had been assigned to portray the situation of the independent refiner. In preparation he canvassed independent refiners for their views, and reported to the committee.

"There is a significant fact which is revealed in this correspondence. It is that the antagonisms, the ill feeling, indeed the bitterness, which were common among the independents of 40 years ago, against the single major oil company of that day, no longer appear. The competition of today is intensely keen; the going is hard at times for the independents, to attain success or even to survive; there are practices, chiefly in the marketing field, which some independents regard as uneconomic or unlawful, or both. But the record indicates that the competition, though tough, has been progressively cleaner. There is no charge of malice. No one has written me suggesting that the executives of the major oil companies are sitting up nights planning evil ways of putting the independents out of business."

He added, though, that there is apprehension that competition will cease unless conditions are such that new companies can enter the business and small concerns can become large. One of the conditions he mentioned was tax treatment which would permit smaller units to build up capital, and he pointed out that in the oil business a small company is of a size considered big in other industries and also by the federal tax laws.

"History repeats," said Wirt Franklin, independent producer of Ardmore, Okla., in discussing the import situation. He was referring to the alarm after World War 1 that this nation was running out of oil and the demand that we import foreign oil and save what little we have left. Once again, he told the committee, our re-

serves have been heavily drawn down to fuel Allied war machines and the alarmists say we are finished as an oil nation and must depend on foreign resources. But once again, he insisted, new reserves will be found if imports are so restricted that the domestic price makes exploration attractive.

From the standpoint of national defense and security the only safety lies in developing our own reserves and a domestic capacity to produce in excess of peacetime demands, Franklin said, picturing the difficulties we would have faced in World War 2 had we been dependent on overseas crude sources. He particularly attacked estimates that domestic production would remain about stationary during the next decade or two while increasing consumptive demands would be met from imports. This, he said, is a picture of a dying industry, and need not be true if the industry is given the encouragement, including protection from cheap foreign flush production, to maintain domestic productive capacity.

Becker Heads Price Discussion

The cost and price of oil was the chief topic of all the independents before the committee. The discussion was headed up by Merle Becker of W. C. McBride, Inc., St. Louis, who presented statistics to show that the real measure of a proper oil price is one which will maintain the ratio of new discoveries to current production. He quoted from the cost survey of the Office of Price Administration advisory committee to show that the current low price not only fails to cover cost of present production but eliminates any expectation of profit from risking funds in replacement operations.

All the witnesses were unanimous in the view that higher crude prices will lead to a big increase in the nation's reserves of petroleum, both through encouraging new exploration and by permitting the continued operation of stripper wells and the adoption of secondary-recovery practices. Most of them felt that the logical top price for crude should be close to $2 or $2.25 per barrel, which is the estimated cost of producing oil from shale.

What to do about stripper wells and secondary-recovery projects occupied a prominent place in the hearings, but opinions were varied. J. D. Sandifer, Jr., of Breckenridge, Tex., past president of the National Stripper Well Association, introduced a number of operators to give their views on subsidy. The general opinion was that at least 25 per cent of the reserves are in old fields where the cost of recovery is around 75 cents per barrel higher than flush-production costs, and the price will have to be paid if the nation wants that oil. Most of the stripper operators preferred a single crude price high enough to compensate all producers, but many doubted that this could be obtained so they supported a federal subsidy as the only alternative to premature abandonment. Sandifer himself likened the stripper subsidy to federal spendings to foster inland waterways, the air mail, soil conservation, and other projects of national importance.

The chief opponent of subsidies was A. Jacobsen, of Amerada Petroleum Corp., who several times raised the objection that subsidies lead to federal price fixing and place a premium on inefficient operation.

As the discussion of prices closed a new twist was put on the subject by B. L. Majewski, of Deep Rock Oil Corp., who said he had learned that the chief reason why OPA was afraid to remove price controls on oil was that state proration bodies would so curtail production as to force a scarcity of crude and a big price rise. To answer this fear he read the committee a telegram from Ernest O. Thompson, of the Texas Railroad Commission, pointing out that under the terms of the interstate oil compact the president of the United States may increase oil imports if the state bodies should ever curtail production below domestic demand.

Vice President H. B. Fell, of the Independent Petroleum Association of America, who had acted as master of ceremonies throughout the hearings, summarized the case for the independents. He made these points:

No Cause for Alarm

There is no cause for alarm over our national oil situation if the Government provides the conditions under which independents are encouraged to explore, namely, adequate price, a sound import policy, a reasonable tax program, and release from unneccessary government restrictions.

If the industry is to remain competitive there must be strong independent units in each of its branches, and nonintegrated operators must be able to make a profit in a single branch in competition with integrated operators. This has not been true under OPA control, since OPA has considered only the earnings of integrated companies.

The position of the independent producer has become worse during the war, chiefly because of unsound government policies, and as a result there is accelerated concentration of production in fewer companies. Yet the independent producer has been the leader in discovery and in secondary recovery.

The independent oil operator can best be aided by a Government policy based on recognition of the fact that discovery and conservation both require an adequate price for oil.

Texas Making Check of Nation's Oil Stocks

AUSTIN, Tex.—Taking another step away from federal guidance, the Texas Railroad Commission has decided to search out its own information on crude stocks throughout the United States.

The commission notified purchasers, refiners and pipe line companies to bring to the allowable hearing April 19 a set of stock figures to that the commission will have "full, adequate, up-to-date data on the question of what are adequate stocks of crude oil of the various types and grades and also how much gasoline and other finished products should be carried on hand at different seasons."

In its notice to purchasers asking that figures for a determination of storage levels be presented at the hearing when May allowables will be set, the commission specifically requested nine figures, all as of March 2:

1. Total U. S. crude on hand.
2. Total amount of Texas-origin crude in U. S.
3. Total amount of crude on hand in Texas.
4. Total amount of crude on hand elsewhere than Texas.
5. Total stocks of gasoline on hand in U. S.
6. Total pipe-line fill in lines in U. S.
7. Total tank bottoms on hand in U. S.
8. Crude stocks for charging to refinery stills in U. S.
9. Active stocks—total U. S. crude less sum of pipe-line fill, charging stocks and tank bottoms.

The commission said it would be "a great help" if the crude storage figures showed various types such as asphaltic and naphthene base crudes, gasoline-producing crudes and lubricating oil producing crudes. It pointed out full production "up to the most efficient rate" had been allowed for certain asphaltic-base crude fields and indicated a similar course will be taken for crudes adapted to producing lubricating oils and fuel oils.

Accompanying the commission's request for stock data was a formal notice of the April 19 hearing which said the commission will consider proration of gas production at the same time. The notice set out the statutory basis for gas proration and directed gas purchasers to submit their May requirements for gas.

In Oklahoma, state officials appeared to be undertaking a somewhat similar study of their own to provide the basis of a market demand estimate. About 60 crude purchasers were mailed forms upon which to report nominations, purchases, stocks, deliveries and other crude movements for the first 3 months of 1946.

THIS WEEK

PRODUCTION—Increases in California and Kansas boost national crude output to 4,423,200 bbl. daily. . . . Texas' output static but state is under severe pressure from Navy to boost yield. . . . Rise of 12,000 bbl. in California daily output reflects Navy demand for fuel oil. . . .

REFINERY MARKETS—Middle West tank-car gasoline prices may advance 1/4 to 3/8 cent per gallon with higher crude costs. . . . ¶Record bookings at summer resorts indicate huge future gasoline consumption. . . . ¶Refiners urged to limit tetraethyl lead orders to immediate requirements. . . . Short supply likely to continue throughout year. . . . ¶Higher ceilings on fuel oils stimulate production. . . . Most agree, however, that price relief came too late. . . . ¶Office of International Trade limits validity of distillate and residual-fuel export licenses to 60 days. . . . Permits previously effective for 1 year from issuance.

CONGRESS—Sen. Joseph O'Mahoney soon to start writing report which may form national oil policy for years to come. . . . Few "clean-up" witnesses remain to be heard. . . . Independents present united front in filling record with pleas for freedom of action, fair tax treatment. . . . Alarm expressed over growth of farm cooperatives in all branches of oil industry. . . . Considered greater threat to independents than bigness of integrated companies. . . . Unequal tax advantages by coop's draws particular fire. . . . Oil men suggest limiting farm coop's to handling agricultural commodities. . . . ¶Triple front attack continued for decontrol of oil prices. . . . Entire industry joins in seeking return of normal economic factors in setting oil prices. . . OPA criticized for wanting to retain control where regulation is no longer needed as inflation preventive. . . .

TRANSPORTATION—War Emergency Pipelines to receive further congressional consideration. . . . War Assets Corp. has several offers for use of lines for petroleum and natural-gas transportation. . . . Disposal of two WEP lines remains top subject among transportation interests. . . . April 3 final date for protesting Trans-Continental application to FPC for use of WEP lines for natural gas transmission. . . . ¶Lea petroleum subcommittee of the House has $35,000 to spend on oil transportation inquiry. . . . Report must be made before current Congress adjourns to qualify for appropriation. . . .

REFINING—Three-hundred refiners receive OPA questionnaire on ability to absorb crude advance. . . . Preliminary price data on finished products may lead to further advances by OPA simultaneous with crude-oil rise. . . . ¶Moderate reduction in gasoline stocks continuing. . . . ¶Eleven war plants offered for sale by WAC. . . . Operating companies express interest in acquiring facilities. . . .

INTERNATIONAL—Soviets reported to have drilled three wells in occupied zone of Iran. . . . Withdrawal of troops eases tension over northern Iran oil rights. . . . Some internationalists advocate way of dividing Iranian oil with Russia. . . . ¶At least four new pool discoveries since start of year reward Venezuelan exploratory drilling. . . . ¶Mexican Gas Co. buys United Gas Co.'s 14-in. line from Roma Tex., to Monterrey. . . . New owner will spend $2,000,000 for parallel line. . . .

Perhaps nowhere is the aviation age so advanced as in South America, where other forms of transportation have not kept pace with the needs. Not Hollywood, but a Brazilian city, boasts this station built like an airplane. The station is in Porto Alegre, Rio Grande do Sul, Brazil. The Public Works and Treasury Building is seen in left background

Decreased Volume, Higher Costs, Lower Prices, Plague Refiners

by Arch L. Foster

FORT WORTH.—The refining industry is confronted with a serious operating situation as a result of decreased volume, generally higher operating costs, and lower prices for gasoline, C. L. Henderson, president, told the membership of the Western Petroleum Refiners Association at the thirty-fourth annual meeting, one of the most largely attended in the history of the association. The meeting opened here March 25.

Henderson, who retires at this meeting after being reelected for six 1-year terms and who served as head of the Association throughout the war period, discussed current problems with which the refining industry is confronted at this time. He said in part: "I want to commend the recent action of the Texas Railroad Commission in reducing the Texas allowable production for the month of March. Production in excess of market demands leads to economic waste, not conservation.

"Wartime needs were met at terrific cost to the oil industry. Crude-oil production was greatly increased and many pools were produced in excess of their optimum rate. Newly discovered reserves are a very small percentage of the oil produced.

"Total estimated underground reserves have about held their own but only because of the increase brought about by revision of estimates for areas already proved.

"The postwar increase in output per man hour so far as the oil industry is concerned is far from a reality. Do not forget that what a man produces eventually determines what he earns. Industrial relations must receive more attention if our system is to survive and expand."

Henderson, who has actively engaged in Mid-Continent refinery operations for many years and who is president of Vickers Petroleum Co. of Wichita, an independent company engaged in all branches of petroleum operations, made a strong plea for the ending of price controls. "There is no longer a shortage of crude oil and its products," Henderson explained. "Since price control in the oil industry was based upon the theory of preventing inflation in prices of scarce commodities, price control on crude oil and refined products should already have been abolished."

Henderson closed his brief talk with a plea for continued cooperation among refiners in the many domestic and international problems ahead.

H. T. Ashton, who was elected president of W.P.R.A., succeeding C. L. Henderson

H. T. Ashton, general manager of the Lubrite division of Socony-Vacuum Oil Co., Inc., St. Louis, was elected president succeeding Henderson. Ashton, whose division operates a large refinery at East St. Louis, has been active in the work of the association for many years as an officer and director. He served as executive vice president of the association during part of the war period.

New President Has Long Record

Ashton became president of the W.P.R.A. after a record of 28 years of continuous service to the organization. He was made a director of the association in 1918. Three years ago, he marked his twenty-fifth year as a member of the board.

Three years after he began his career in the petroleum industry in 1913, Ashton assisted in designing and building one of the largest compression-type natural-gasoline plants then in existence at Dawes, W. Va. He went to Tulsa in 1918 as general superintendent of Pure Oil Co.'s refineries at Cushing and Ardmore, Okla., and in 1921 became division manager.

A year later, he became vice president and general manager of Lubrite Refining Co. in St. Louis and remained as president and general manager of Lubrite after an affiliation with Vacuum Oil Co. in 1929. One of the first successful vapor-phase cracking units was built at the Lubrite refinery after experiments and development work by Ashton and C. L. Pratt.

Other officers for the coming year are: Vice presidents. R. W. McDowell, vice president, Mid-Continent Petroleum Corp., Tulsa; T. M. Martin, vice president, Lion Oil Co., El Dorado, Ark.; R. L. Tollett, president Cosden Petroleum Corp.; T. A. Helling, vice president, El Dorado Refining Co., El Dorado, Kans. J. C. Day was elected secretary, and Lucille Dennis, assistant treasurer. Fayette Dow will continue as Washington counsel of the association. Retiring President Henderson commended the work of the Tulsa and Washington staffs of the association.

Research Committee to Meet

At an active session of the diesel-fuel research committee, arrangements were completed for a meeting of the cooperative fuel research, the W.P.R.A. diesel-fuel committee, the Diesel Engine Manufacturers and the U. S. Bureau of Mines. The meeting will be held in Chicago April 10 at the Palmer House to round out and complete the program of research on diesel fuels. This program has been under development for several months as a cooperative program among these agencies. The following day the diesel fuel committee will meet and formulate the program in the light of all suggestions received from all groups participating, and will determine details of how the program will be carried out.

The W.P.R.A. motor fuel and tractor fuels committees held a joint meeting to consider the numerous problems of supply and the market situation in prospect for the spring period.

Ernest O. Thompson, member of the Texas Railroad Commission, discussed status of the refining industry in Texas. He pointed out that the state has 97 refineries with a daily capacity of 1,441,745 bbl. Texas' consumption of gasoline, he said, totals 359,064,000 gal. per month. Reference was made to gas conservation and to the commission's program for removing all liquefied hydrocarbons before gas is returned to reservoirs for pressure maintenance or into lines for delivery to eastern industrial and domestic markets. Thompson said the Railroad Commission studies indicated that a properly designed refinery can actually realize close to 40 cents more profit out of refining a barrel of 60-gravity charge stock than out of a barrel of 40-gravity crude.

Solution of the equation involving the economics of modern processes, and the demands of the market for

product quality overshadowed most other major questions in the minds of the independent refiners attending the meeting. Problems of adapting refining methods to the making of 78-80 octane number housebrand motor gasolines in the near future instead of the 74-75 octane fuels produced prewar are causing refiners most concern.

Technical leaders have shown the technology, operating technique, and economics of catalytic cracking, the large new joker in the refiner's deck of cards. Calculating the over-all costs and returns for a refinery operation on 5,000 bbl. of crude per day, involving combinations of thermal and catalytic cracking, thermal reforming, polymerization, and auxiliary operations, Noll and collaborators in one technical paper showed the refiners a payout period of 2.45 years on one processing arrangement in a plant costing nearly $1,000,000. In a plant costing $150,000 more, the payout time was nearly 3 years. In each case the processing plan is based on Thermofor catalytic cracking operations.

Fuqua Discusses Pressure Drop

Pressure drop is probably the most critical of all variables in desalting crude, F. Duane Fuqua, engineer for Ben Franklin Refining Co., told W.P.R.A. members when discussing the methods employed to remove salt from crude prior to processing. For the particular crude discussed a pressure differential across the emulsifying valve of 40-50 lb. has proved satisfactory. If this pressure differential rises to 75-100 lb. an emulsion may be formed which may be difficult to break. Pressures in the salt removal system range from 200-210 lb. at the crude pump to 140 lb. at the horizontal settler outlet.

Relation between temperature and viscosity is important also in removing salt. Viscosities of about 40 seconds Saybolt Universal give good results in the plant operations, and temperatures should be determined which will give a viscosity for any given crude which will show good settling and salt removal. A typical operation holds the temperature of a given crude at 220° F., viscosity at 34 S.U.S., a pressure drop of 40-50 lb. across the emulsifying valve, and a water flow rate of 5-15 volume per cent of the crude flow; 90-95 per cent salt removal is obtained under these conditions. Switching suddenly to a crude which shows 50 S.U.S. viscosity at the same temperature an excessive water and salt carryover was found, requiring raising temperature to reduce viscosity.

No single type of stainless steel can be considered a cure-all for the ills of corrosion in refinery equipment, according to John S. Ewing of Carnegie-Illinois Steel Corp. The 5-per cent chromium-molybdenum type has shown good service in "cold end" refinery application but straight chrome steels must be used with care if hydrochloric acid may be formed by hydrolysis of magnesium chloride or from any other source. Sulfur dioxide or trioxide is also deleterious to such chrome steels. One of the best steels is 18-8 chrome nickel which also contains 2 to 3 per cent of molybdenum, especially where sulfuric, hydrochloric, or phosphoric acids, sulfurous acid or wet hydrogen sulfide, or many organic acids must be handled. Vacuum and pressure relief valves must function perfectly, therefore seat and disc should be of 18-8 steel, Ewing stated.

Stainless W is a new steel, developed during the war, and contains about 17 per cent chromium, 7 per cent nickel, 0.7 per cent titanium, 0.2 per cent aluminum and 0.07 per cent carbon. This steel is magnetic, thus being unlike 18-8 steel. One of its outstanding properties is the great uniformity of hardness throughout the cross-section of bars, etc. It is not susceptible to intergranular corrosion, or "embrittlement," Ewing said.

J. H. Reppert, fuel division of OPA, urged refiners to supply the information now being requested by the national refiners' industry advisory committee to determine the earning position of refining organizations as a guide to adjustments in price ceilings and also to determine when all price controls in the petroleum industry should be ended. Reppert explained that OPA will lift price controls in the oil industry as soon as the legal requirements of the OPA act are complied with.

"We do not feel we can act too hastily because of the position of the independent refiner," Reppert said. "In the first place he probably did not prosper to the same extent that larger integrated companies did during the war due to concentration of the production of war goods. At the same time the independent refiner is now facing the same sort of problem that confronts the major operator and that problem is one of attempting to obtain a sufficient price for refined products to meet current operating costs. For some time it seems reasonable to believe that prices for refined products will not advance generally under a free price economy. They may in fact not go higher than the present prices for the balance of this year. This being true the relatively higher OPA prices that I speak of as the legal limit will provide some flexibility as compared to present price levels which I believe will assure us that it will not be necessary to reinstate price control after they have been dropped due to inflationary trends."

Two Petroleum Installations Still Remain Under Navy Control

THE number of Navy-operated oil properties still without labor agreements was reduced to two this week while the Hughes Tool Co. dispute in Houston showed its first signs of settlement.

The last of the pipe line systems among the 53 oil installations seized by the Government last October in the climax of a nation-wide strike was to be returned to private management. It was Pan American Pipe Line Co. which reached an agreement with its workers in Texas last week.

The second settlement was between the oil workers' union and Gulf Oil Corp. for the company's Port Arthur, Tex., refinery. With a bargaining unit of about 4,000, the plant was one of the largest under Navy control.

Left on the Navy list without reported settlements were Gulf Refining Co. at Toledo, Ohio, and American Liberty Oil Co. at Texas City, Tex.

Noah Dietrich, executive vice president of Hughes Tool Co., a major manufacturer of drilling bits and other equipment, met last week in Washington with Phillip Murray, president of the C.I.O. and the affiliated steelworkers' union. On his return to Houston, the company executive said "little was accomplished except improved relations which I believe may lead to a settlement."

Main stumbling block in the dispute appeared to be an unfair labor practices charge which the steelworkers' union has filed against Hughes with the National Labor Relations Board. Dietrich contends the C.I.O. union no longer represents a majority in the plant. However, while the charge is pending, no election can be held.

Elsewhere the C.I.O. union gained bargaining rights in two NLRB elections among oil industry employes. Workers in Pan American Refining Corp. at Texas City voted 733 to 251 to continue the C.I.O. union as their agent in an election which was requested by an independent labor organization. Employes of Standish Pipe Line Co. in the operations and maintenance division in the Pampa area of the Texas Panhandle voted in favor of the C.I.O. group.

Civilian Gasoline Consumption Seems Headed for New Record

by Dahl M. Duff

GROWING indications that the coming summer will see the greatest flood tide of travel in the nation's history are giving promise that the huge surplus of gasoline will be cut far more than many market observers thought possible a few months ago.

Reports of solidly booked reservations for accommodations throughout the country, record numbers of requests on automobile clubs for routings, preparations of resorts for more tourists than in 1940, are providing the basis for the more encouraging forecasts of gasoline-market conditions a few weeks hence.

In the week ending March 16, daily gasoline demand stood at 1,996,000 bbl. daily, off only 2.07 per cent from the heavy war demand at the same time in 1945. The March 16 figure represented a 106,000 bbl. gain over the preceding week.

The immediate gasoline market was reported firm in both the Middle West area and on the East Coast. Several Mid-Continent refiners were said to be planning gasoline quotation raises when the 10-cent crude increase authorized by the Office of Price Administration takes effect late this week.

Speculation centered on the likelihood of an upward move of gasoline prices as a result of the additional crude cost. Some of the pressure for high gasoline prices, now ranging considerably below ceiling, was believed removed by action of OPA in granting ceiling increases to heavier refined products.

Supply of some grades of fuel oil which have been in critically short supply were reported easing. In recognition of the domestic shortage, the Department of Commerce last week began limit licenses for export of distillate and residual fuel oils to 60 days from the date of issuance. Previously, licenses were good for 1 year.

In view of the shortage and the bluntly-phrased Navy demands for more fuel oil, refiners were making a determined effort to obtain better prices for residual sold to railroads, but the situation was described as still obscure.

One company executive said the railroad residual price situation should crystallize within a week or 10 days. Prior to the recent OPA action in raising residual prices 21 cents, refiners were reported to be obtaining 90 cents for railroad residual, against a ceiling price of 97 cents.

Some railroad-refinery contracts were understood to provide that the price paid would absorb 60 per cent of the advance or decline in crude prices. With a 10-cent crude raise, this would give the refiners 96 cents for residual, against a ceiling raised 21 cents to $1.18. One railroad was reportedly offering $1.05 for residual, but some refiners were reported to be asking $1.11—21 cents above the former top of 90 cents. "There are about as many types of railroad residual contracts as there are companies," said one refiner.

Production of Synthetic Rubber Reached Nearly 700,000 Tons in 1945

by Warren W. Burns

NEW YORK.—Indicating the gigantic task accomplished by the nation's $700,000,000 synthetic-rubber plants, during the years 1941 through 1945, the Rubber Manufacturers Association points out that military necessity drove synthetic-rubber consumption in this country from 6,000 tons in 1941 to a record-breaking 693,392 tons in 1945.

The U. S. consumed 781,259 tons of natural and synthetic rubber in 1941, and of this total synthetic pilot plants contributed less than 1 per cent, R.M.A. points out. Production was still actually on a pilot-plant basis when the Japs swept down through the Malayan peninsula and into the Netherlands East Indies, thus cutting off more than 90 per cent of the world's natural-rubber supply.

Since the Jap surrender, 3,366 long tons of rubber—900 from Java through Tandjoengpriok, Batavia's port, 230 through Pontianak, Borneo, and 1,136 through Belawan from the Deli district of Sumatra—have been exported from the East Indies, according to figures from the Netherlands Indies Government Rubber Institute in Batavia.

On Java and Sumatra, 95,400 long tons are stored, and an additional 400 tons on the islands of Bangka and Billiton, off the east coast of Sumatra, the institute reports, adding that it will be shipped as soon as vessels are available.

Imports Less Than Estimated

However, despite the natural crude rubber already shipped and plans to increase more, authoritative sources here in New York state that overseas shipments from the East Indies, in the current quarter, probably will fall short of earlier estimates, due to internal disorder there. A few weeks ago, rubber officials predicted that rubber would be moving out of the islands in such quantities in the near future that the prewar production of 650,000 tons annually might be available for export by the end of 1946. But the unsettled political situation there apparently will keep exports down for some time to come.

Meanwhile, Civilian Production Administration's rubber advisory committee stated, in February, that because of the difficulty of restoring production of natural rubber in liberated Far Eastern areas it would be 2 or more years before American industry can return to unlimited use of the natural product.

Currently, Reconstruction Finance Corp. is buying natural rubber, in the Netherlands East Indies, at 20¼ cents per pound. In comparison with this is the fact that at the end of 1945 the Government's general-purpose synthetic rubber, (GR-S), was selling for 18½ cents per pound, while neoprene (GR-M) sold for 27½ cents per pound, and butyl (GR-I) sold at 33 cents per pound. The 20¼ cents per pound for natural rubber becomes 22 cents to 22½ cents by the time it arrives in the U. S., indicating that the general-purpose synthetic rubber can be sold about 4 cents cheaper than natural rubber.

A comparison of crude and reclaimed rubber imports (natural) and synthetic output is shown (in long tons) in the accompanying table:

Year—	Natural	GR-S	GR-M	GR-I	All other	Reclaim
1941	775,000	108	4,463	.....	1,688	251,231
1942	376,791	2,579	6,833	22	8,217	254,820
1943	317,634	131,977	26,205	304	12,405	291,820
1944	144,113	495,552	46,243	10,763	14,112	251,083
1945	105,406	600,001	42,363	43,009	8,019	240,780

INTERNATIONAL

Floyd Succeeds Knowlton As Phillips Vice President

Don R. Knowlton has resigned as manager of the foreign department of Phillips Petroleum Co. to join a new drilling and consulting petroleum engineering firm with Frank M. Porter of Fain-Porter Drilling Co., Oklahoma City.

F. W. Floyd, formerly production executive of Carter Oil Co. who joined Phillips about a year ago, has been chosen to succeed Knowlton as manager of the foreign department and executive vice president of Phillips foreign subsidiaries—Phillips Venezuelan Oil Co., Phillips Colombian

F. W. FLOYD

D. R. KNOWLTON

Oil Co., Phillips Magdalena Oil Co., and Phillips Morales Oil Co. Floyd, who has been Phillips South American manager and in active charge of operations, will continue to maintain headquarters in Caracas, Venezuela.

Knowlton has been with Phillips the last 20 years except for 2½ years when he was director of production, Petroleum Administration for War. The partnership with Porter will engage in drilling contracting and will establish the consulting service after making a survey to determine needs of the industry in various phases of petroleum engineering.

Two other changes in personnel in Phillips' organization involve S. S. Learned, elected director and vice president of each of the company's foreign subsidiaries, and L. L. Leedy, appointed assistant to the manager of the foreign department in charge of the Bartlesville, Okla., office.

Creole's Venezuelan Production Increasing

Daily crude-oil production for Creole Petroleum Corp. in Venezuela increased 1,475 bbl. during February as compared with January, while the company's daily refining operations for the same periods, dropped 10,735 bbl.

The daily average crude production in February was 514,348 bbl., compared with 512,873 bbl. in January. Daily crude production for February 1945 was 407,935 bbl. Daily crude runs to stills in February of this year was 58,293 bbl., compared with 69,028 bbl. during January.

February's crude production figures show that 358,074 bbl. were drawn from the Lake Maracaibo area and 156,348 bbl. from eastern and other areas (including Cumarebo). Refinery throughput averaged 48,633 bbl. daily at Caripito, and 9,660 bbl. daily at La Salina. This compares with January's throughput of 38,691 bbl. at Caripito and 30,337 bbl. at La Salina.

A total of 24 oil wells were completed in February with no gas wells and no dry holes. In January Creole reported 18 oil wells completed with no gas wells and one dry hole. The number of wells completed in February and the fields follow: Bolivar Coastal (B.C.F.), nine; Mulata, four; Jusepin, nine; and Quiriquire, two.

Average initial production in February was highest in Mulata with 424 bbl., with the other three fields showing: B.C.F., 403; Jusepin, 395; and Quiriquire, 366.

The average well depth in the four fields with February completions was: Quiriquire, 7,404; Mulata, 5,973; Jusepin, 5,129; and B.C.F., 4,316.

Argentine Output Down

BUENOS AIRES.—Argentine crude production in the first 9 months of 1945 dropped 5.9 per cent from that in the corresponding period of 1944 and was reported at 17,162,032 bbl. Of this total, slightly more than 67 per cent, or 11,572,116 bbl., was produced by state-owned oil fields operated by Yacimientos Petroliferos Fiscales.

Russia Cannot 'House' United States Oil Attache

WASHINGTON. — The State Department has just been informed that "no housing is available" for the petroleum attache which the United States had planned to send to Moscow. At first, Moscow agreed to the proposal to have a petroleum attache stationed in Russia, but now, apparently, has altered this decision.

Norman Keith, who was slated to be sent in this capacity, is planning to return to private industry. During the war he was a Navy lieutenant, in Washington, handling lend-lease oil, devoting most of his time to the Russian aspects of these transactions. Michael Chritzko, California - Texas Oil Co. employe before the war, was slated to go along as assistant petroleum attache, but will return to Caltex after his discharge from the Army.

Mexican Production Shown

MEXICO CITY. — Oil production from three Mexican fields—Poza Rica, Naranjos, and Panuco — showed a slight drop in December. Daily average production during the month was 101,895 bbl. Reports formerly were compiled for the 30-day period ending the 19th, and the period ending December 19, daily average production was placed at 104,290 bbl. Stocks in field tanks and terminals in the three fields totaled 3,759,758 bbl. December 31, compared with 3,811,432 as of December 18.

Slight Increase Noted in Colombian Crude Output

BOGOTA. — Colombian oil production in 1945 rose to 22,756,783 bbl., an increase of 109,308 bbl. over the 1944 total. Of the 1945 production, 19,487,135 bbl. were exported.

A sharp drop in production from the De Mares concession of Tropical Oil Co. was offset by an increase from the Barco concession operated by Colombian Petroleum Co. and by production of 1,622,550 bbl. from the Yondo concession of Compania Colombiana de Petroleo el Condor (Shell).

DAILY AVERAGE PRODUCTION
(Barrels per day)

Operator and Concession—	1944	1945
Tropical, De Mares	49,540	42,847
Texas-Socony, Barco	12,500	15,054
Condor (Shell), Yondo		7,800
Total	62,040	62,350

Iraq to Meet Needs With New Refinery

BAGDAD. — A supply of refined product sufficient to meet domestic demands is sought by the Iraq Government through its new refinery project at Baiji in the northern part of the country.

London engineers who drew up the refinery plans before the war have been asked by government authorities to review the project and bring it up to date, according to reports here. Bids will be asked when the new designs and specifications are completed.

Capacity of the plant is expected to be about 300,000 tons (2,248,300 bbl.) a year. The small Anglo-Iranian Oil Co., Ltd., plant at Alwand, near Khanaqin, at present partially meets Iraq needs for refined products. Additional supplies come from Abadan.

Walter S. Hallanan, chairman of the A.P.I. committee opposing continuance of price control, and Frank M. Porter, president, Mid-Continent Oil and Gas Association, were among the critics of OPA testifying before the House committee last week

Attacks Against Price Control Pressed on Triple Front

WASHINGTON.—A triple attack on oil-price control was pressed by petroleum industry spokesmen here last week.

Before the House committee on banking and currency, which is considering legislation to continue price control for another year, the industry argued that no control whatever is needed for the future because ample supplies of oil are available to prevent inflationary prices.

Simultaneously the Senate petroleum resources committee heard independent producers expound the case that the price of crude has been held too low to permit new exploration and complete recovery from older fields.

At the same time officials of the Office of Price Administration were in conference with the national crude oil industry advisory committee over proposals for a further study of crude-production costs.

Prospects for quick action from any source are not good. The House committee is being bombarded with demands from so many industries to be removed from control by OPA that it might dodge the issue by recommending continuation of the existing law without change. However, there are good prospects that somewhere in the Congressional mill the bill will be amended to require OPA to remove controls from commodities which are no longer scarce. Such an amendment, if worded forthrightly, would end OPA's connections with petroleum, but it presumably would not be effective prior to June 30.

The Senate hearings promise even less in direct results, because the committee is an investigative, rather than a legislative, group and it is already sympathetic with the demand for higher crude prices. However, its members will vote on continuing OPA, and their memories have now been refreshed on the oil situation.

Another Cost Study in Offing?

Slowest action of all is expected from OPA itself. When the 10-cent price increase was announced, OPA promised to make an immediate study of crude-production costs to see whether or not a further increase is called for under the agency's own rigid pricing formula. That was the subject of the conferences with the advisory committee last week, but the only result was a decision to hold more conferences later. Administrator Paul Porter and other top OPA officials greeted the group cordially but promptly turned the matter back to the lower-level employes who have been studying oil prices for years. The situation was not a bit altered by the departure of Sumner Pike, who resigned last week from Securities and Exchange Commission and from his side job as chief of OPA fuels section.

The same OPA men who kept the crude-cost study up in the air for a year are now talking about getting ready to start another cost study. They are also talking about a study of the possibilities of suspending oil-price control. By suspension is meant an order freeing both crude and products prices from OPA control under the stipulation that they not go up appreciably; but if prices should rise above a designated figure, OPA would step back in and impose ceilings.

The demand for legislative action was presented by witnesses selected by American Petroleum Institute and Independent Petroleum Association of America. They told the House committee that there is no further need for price control over petroleum because there is no shortage of crude oil now or in early prospect, there are ample refining and distribution facilities to supply all markets, and the competitive nature of the oil industry will prevent material increases in prices if OPA control is removed.

The lead-off witness was B. A. Hardey, president of I.P.A.A., who dealt with the apparently anomalous argument that OPA has kept crude prices too low and yet there is so much oil available that prices would not rise much if controls were removed. He gave the committee an illustrated booklet his association had prepared on the thesis that plenty of oil will be available at reasonable prices only if more oil is discovered as fast as it is used up.

He explained that OPA froze crude prices at an abnormally low point and has kept them below the cost of finding new oil to replace that being used. Let the price rise enough to provide an incentive to find new sources of production and there will soon be sufficient crude capacity to safeguard consumers against high prices caused by a shortage, he pleaded.

The effect of a free market on prices of petroleum products was discussed by B. L. Majewski, of Deep Rock Oil Corp., who read official figures to show that there is ample refining capacity to meet all present and prospective demands for any and all products. Only OPA price ceilings are responsible for the current shortages of fuel oils and the oversupply of gasoline, he insisted, explaining that flexibility in pricing would have permitted refiners to make more of the scarce products and less gasoline without material increases in their over-all earnings. Because OPA acted too late, it had to increase fuel-oil prices higher than the amounts which the industry had estimated, at the beginning of the heating season, were necessary to bring out the desired quantities, he declared, but these increases are now correcting the unbalanced inventory situation and are resulting in larger production of the needed products.

This proves, Majewski argued, that

no Government agency, can act promptly and wisely enough to replace the flexibility of automatic price adjustments in a multiple-product industry, and that if left alone the oil industry can protect the public both as to supplies and prices.

Support from the State of Mississippi came from H. M. Morse, oil and gas supervisor and representative of Gov. Thomas L. Bailey. An end to price controls, he asserted, would greatly stimulate prospecting and the development of new oil resources in his state, and he assured the congressmen that the industry is so competitive that there is no danger of excessive prices even though the price of crude should go up sufficiently to cover production costs.

The price of crude must be allowed to rise sufficiently to cover costs of secondary-recovery operations if the nation is not going to lose the huge reserves remaining after flush production stops, the committee was told by Donald P. Oak, Tulsa producer. He expressed the belief that the oil industry, if left to itself, will adjust to prices based on the cost of producing and replacing crude which will be sufficient to permit operation of most stripper wells and secondary-recovery projects.

Counsel Flays OPA

Price-control officials were flayed with their own words by Russell B. Brown, general counsel of I.P.A.A., who quoted the promises of various Government officials that price controls would be removed from any commodity as soon as it ceases to be scarce. Since OPA has failed to carry out these promises, he argued, Congress should require it by an amendment to the law.

"We can only conclude," Brown said, "that OPA likes price control merely for the sake of control. It is unresponsive to the facts which are apparent to all. It is intent on following a line that was established in 1941 and, for all we can now conclude, it will, in the absence of congressional direction to do otherwise, maintain price ceilings on petroleum for the entire time it has authority to do so."

The need for price controls in the oil industry ended when rationing was dropped, Brown said, quoting many Government officials and statistics to prove that supplies are adequate but that OPA has held prices below production costs.

Walter S. Hallanan, of Plymouth Oil Co., presented "the unanimous plea of the petroleum industry—every segment and division of it—to be relieved from the straitjacket of federal price control. Instead of holding the price line it is now realized that OPA is holding up the production line."

The facts are simple, Hallanan said. Oil prices were frozen at a depressed and abnormally low level and were held throughout the war at less than production costs. Since there is sufficient oil to meet all demands, prices would rise only enough to compensate for present costs. Such an increase would be in the public interest because it would encourage the discovery of new reserves to meet future demands.

Wilson Relates Refinery Conditions

Refinery conditions were described to the committee by Dr. Robert E. Wilson, of Standard Oil Co. (Indiana), who declared that the present excess refining capacity is sufficient to prevent any unwarranted increase in products prices but that continuance of present price controls causes serious dislocations of supply and is pauperizing the industry. The only shortages of any products since the war have been those caused by OPA's disregard of repeated warnings that the frozen industry price structure did not fit the postwar demand pattern.

"Our industry," said Dr. Wilson, "is a clear case of one where capacity to produce and refine at a rate above demand has not been recognized by OPA in spite of its promise to decontrol when such a situation exists. We are not only suffering from a price straitjacket but we are tortured by one which is a bad misfit for the present demands of our customers. Our industry is one in which frequent price changes are absolutely necessary in order to keep our yields adjusted to fluctuating seasonal demands for different products.

"The plight in which the refining branch of the industry finds itself is an outstanding example of the undesirable effects of price control, which has created shortages in spite of repeated warnings, and has required months to grant price adjustments which are clearly justified. There has never been a peacetime shortage of any petroleum product in this country until under price control we had those of the past winter. Does the public really want a price-control system which has been creating shortages when plenty could have been made available, which restricts the introduction of new products and qualities, and which, if continued for very long, will result in a pauperized industry unable to meet the nation's petroleum needs?"

The views of the Mid-Continent Oil and Gas Association—which were the same as those of the other associations—were presented by its president, Frank M. Porter, but he added one important point. Not only should Congress provide that controls be lifted when supplies balance demand, he said, but it is highly important that the statute be made self-executing and not left to OPA to apply. He suggested that when an industry advisory committee, set up as provided by the present law, certifies that the prescribed conditions have been met, OPA be required to drop price controls at once. While crude prices would go up enough to cover present costs, an advance of perhaps 35 cents per barrel, Porter assured the committee there would be no big increase in refined-product prices because of the large supplies and competitive conditions.

The peroration for the industry was delivered by J. Howard Pew, president, Sun Oil Co., who hardly mentioned the word oil. He made a defense of free enterprise and competition in general and a bitter denunciation of Government controls as being the present cause of shortages and of inflationary pressures. Failure to realize the difference between price control in war and in peacetime, Pew insisted, has curtailed production, delayed reconversion, and created artificial shortages.

"American industry and business cannot be operated by formulas," Pew declared. "If they could, it would have been figured out years ago and all business enterprises would be successful while their managers could go on year-long vacations. Day-by-day judgments and decisions are essential to business operations. Enterprises are successful when they adjust themselves to changing conditions. They retrogress when they become static.

"If the existing OPA price-control powers are continued for another year the price-control administrator will be back here next year pleading for an extension for another year, using the same arguments they propound this year, with this one exception: Next year they will be able to plead a worse situation and a greater urgency, for continued price control meanwhile will make the problem worse, just as our situation today is more critical, in the words of Chester Bowles, than it was at the end of the war."

Kansas Rescinds Wartime Rule Allowing Dual Completions

WICHITA, Kans. — Another wartime production stimulant went into the discard here when the conservation division of the Kansas Corporation Commission rescinded its order permitting two-strata completions.

Production from two formations will come to a gradual end in the state. As packers in existing two-strata wells come up for replacement, operators will be permitted to choose the zone from which production will continue.

The division said it had studied about 80 types of packers installed in dually-completed wells but that none had satisfactorily prevented leakage. The wartime emergency rule was originally designed to conserve production materials.

Public Land-Policy Change Sought by U. S. Chamber

WASHINGTON. — The United States Chamber of Commerce is polling its membership on recommendations of its natural resources committee that changes be made in the Government's public-land policy, including liberalization of oil and gas leasing and royalty regulations.

Oil land leasing policies need revision in the light of the current urgency for developing new sources of oil the committee says, and recommends that the acreage limitations on leases in any one state or on a single geologic structure be enlarged or removed in order to encourage geophysical prospecting. It also recommends a flat 12½ per cent royalty for all leases not on proven structures in place of the various rates now in effect and that the Government take its royalty in kind or at the market price and also recommends free right of assignment of oil and gas leases without specific approval of the Interior Department.

Other recommendations are that Congress continue its study of public-land policies, that lands withdrawn from use be reexamined and released where possible, and that all lands acquired by various government departments be sold as surplus or administered by the Interior Department with the same rights to develop their mineral content as lands in the original public domain.

The chamber committee which drew the report includes Eugene Holman, president of Standard Oil Co. (N. J.); Albert C. Mattei, president of Honolulu Oil Corp.; James Tanham, vice president of The Texas Co., and J. S. Bridwell of Bridwell Oil Co.

Committees Organized for Shreveport A.P.I. Meeting

DALLAS.—The committee organization to handle details of the spring meeting of the southwestern district of the American Petroleum Institute's division of production has been announced by W. E. Winn, Sun Oil Co., district chairman.

The 2-day meeting will open May 17 in Shreveport with the Washington-Youree Hotel as headquarters. The Ark-La-Tex chapter of the division, of which B. J. Dowd is chairman, will be official host to the visiting engineers and production executives.

Committees and chairmen follow: General committee on arrangements, H. C. Anderson, Texarkla Oil Corp., Shreveport; program committee, W. V. Vietti, The Texas Co., Houston; registration committee, R. E. Bridges, Humble Oil & Refining Co., Houston; hotal arrangements committee, Sam W. L. Backus, Mid-Continent Supply Co., Shreveport; publicity committee, H. L. Kirkpatrick, Arkansas Fuel Oil Co., Shreveport; and entertainment committee, V. J. Martzell, Rosenbloom Pipe & Supply Co., Shreveport, chairman.

Three Societies Ready For Chicago Meeting

CHICAGO.—More than 2,000 exploration scientists will gather at the Stevens Hotel here April 1-4 for the joint annual meetings of three geological and geophysical professional societies.

Scheduled for April 2-4 is the 31st annual meeting of the American Association of Petroleum Geologists. Beginning April 1 is the 2-day 20th annual meeting of the Society of Exploration Geophysicists. The 20th annual meeting of the Society of Economic Paleontologists and Mineralogists is set for April 3-4.

High point of the meetings will come the night of April 2 when Eugene Holman, president of Standard Oil Co. (N. J.), speaks of "Facing Forward." Holman himself is a geologist and a long-time member of the association. The program is filled with technical papers, committee meetings and other sessions. A dinner dance is set for April 3 with the association's annual business meeting following the next afternoon.

Water Disposal Hearing Due

AUSTIN, Tex.—A hearing to determine whether water produced with oil in Archer and Wichita counties should be returned to the horizon has been scheduled by the Texas Railroad Commission April 3. The commission said it has found a considerable quantity of water produced with oil in the two counties is causing surface contamination and pollution.

Index Now Ready

The most complete editorial index the Journal has ever compiled is now available and copies are being sent to readers who request them. This 40-page folder provides the reader with a ready reference of articles and material published in the Journal during 1945. Due to continued paper shortage the index was not bound into the magazine but it will be sent without charge to all subscribers requesting a copy. Address requests to Circulation Department, P. O. Box 1260, Tulsa 1, Okla.

Strickland Named Head of Southern Gas Association

GALVESTON. — Dean S. Strickland, general sales manager of United Gas Corp., Houston, was elected president of the Southern Gas Association of the organization here last week.

Strickland succeeds Frank S. Kelly, Jr., Arkansas - Louisiana Gas Co., Shreveport. Other new officers include W. L. Woodward, president of Zenith Gas System, Inc., Alva, Okla., first vice president; W. H. Ligon, president of Nashville Gas & Heating Co., Nashville, Tenn., second vice president; and L. L. Dyer, comptroller of Lone Star Gas Co., Dallas, treasurer.

Arrangements Committee Named for A.P.I. Meeting

OKLAHOMA CITY. — Harold S. Kelly, Phillips Petroleum Co., Bartlesville, Okla., has been appointed chairman of the arrangements committee for the Mid-Continent district spring meeting of the American Petroleum Institute division of production to be held at the Skirvin Hotel here June 6-7.

Assisting Kelly are C. N. Coleland, Williams-Copeland Drilling Co., Tulsa, and W. L. Horner, Barnsdall Oil Co., Tulsa. Other committees will be named later, said J. S. Montgomery, district chairman.

Skelly Well in East Texas Gages 480,000,000 Cu. Ft.

CARTHAGE, Tex. — What is believed to be the world's largest gas well, Skelly Oil Co.'s 1-D Werner in the eastern edge of the Carthage gas-distillate field, has been tested for a reported 480,000,000 cu. ft. daily.

The well, located on the Lewis Werner Sawmill Co. tract in Panola County, was backed up to retest the upper Pettit lime from 5,854-90 ft. The test was made on a Bureau of Mines basis, and bottom-hole pressure was reported steadily increasing when it was ended.

Penn Crude Group to Meet

OIL CITY, Pa.—The twenty-third annual meeting of the Pennsylvania Grade Crude Oil Association will be held June 27-28 at the William Penn Hotel in Pittsburgh. The membership meeting will be the first since 1944. Directors of the association set the date at a meeting here last week at which they also designated J. P. Jones, association production director, to represent the organization at the Charleston, W. Va., Federal Power Commission hearing April 2 in the natural gas industry investigation.

Bacon Retires as Head Of Engineering Firm

NEW YORK. — George W. Bacon, one of the founders of the engineering firm of Ford, Bacon & Davis, Inc., has retired from the chairmanship of the board which he has held the last 18 years.

The announcement of the retirement came last week on the fifty-second anniversary of the day that Bacon, together with the late Frank R. Ford, and George H. Davis, now retired, started the organization. Bacon, who returned recently from a tour of India and China, was honored at a dinner attended by 200 leading industrialists, bankers, and other leaders.

The firm, well known among oil engineers and executives, during World War 2 did a business of more than $1,000,000,000, requiring more than 25,000 employes in design, construction and operation of a variety of plants.

More Stripper Subsidies Authorized for 10 Pools

WASHINGTON.—Crude oil stripper subsidy payments have been extended to eight more pools and increased in two others.

Pools and amounts per barrel granted follow:

Texas: Beddo, 25 cents; Cayuga, 31 cents; Sayles, 5 cents; (previously authorized for a 20-cent payment); Stoneburg, 14 cents; and Tenney Creek, 25 cents.

Arkansas: Champagnolle, 35 cents.

Michigan: Zeeland, 25 cents.

Kansas: Jerry (Lansing), 6 cents.

Oklahoma: Shawnee, south, 7 cents; and Weleetka, 10 cents (previously authorized for a 25-cent payment).

Fire Destroys Part of Pure Oil's Heath Plant

NEWARK, Ohio.—A part of Pure Oil Co.'s Heath refinery near here was in ruins this week as a result of a series of explosions and a fire which caused the death of two employes and damage unofficially placed at $1,000,000.

The first explosion occurred at 7:38 p.m. last Friday in the largest of the high-pressure units. Fire spread to another smaller unit, causing three more explosions in 45 minutes. No cause for the fire has been determined. It was extinguished after a 3-hour battle by firemen.

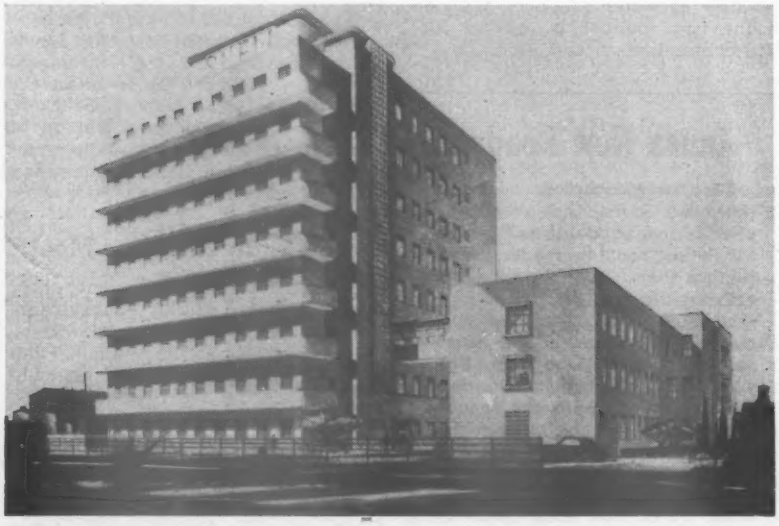
Dead were Nathaniel J. Skarin, Jr., and Benjamin Gerber, both on duty at the time. Officials of the refinery planned to begin a search for a possible third body as soon as the debris cooled.

Shell Plans $3,500,000 Laboratory Expansion

Further evidence of the extent of the interest of American oil companies in postwar scientific research is furnished by the announcement of Shell Development Co. of a $3,500,000 expansion program for its Emeryville, Calif., laboratories.

Shell's announcement follows disclosure of similar plans by several other leading companies. The Emeryville improvement includes construction of three major new buildings and extensive remodeling of present facilities which will allow an increase of personnel from 600 to 1,200. The Shell research organization was established in 1928 with a staff of 35.

Work is due to start this spring and will continue over a 2-year period. Allison & Rible, Los Angeles, are architects for the project. Shell Development Co. is a subsidiary of Shell Union Oil Corp.



This architect's sketch shows the proposed expansion of Shell Development's research laboratories at Emeryville, Calif.

Early-Day Oilmen Invited To Electra Celebration

ELECTRA, Tex.—Several hundred oil men who went to the Electra area following the discovery 35 years ago have been invited to a Chamber of Commerce-sponsored celebration here March 31-April 1 in commemoration of the event.

The program includes dedication of a bronze plaque at the site of the Clayco 1 Woodruff-Putman wildcat which blew in April 1, 1911, to mark the beginning of North Texas development.

DEATHS

Charles W. Dingman, 57, actively associated with Alberta oil development since 1913, died recently in Calgary. He was associated with his uncle, the late A. W. Dingman, in Calgary Petroleum Products whose Turner Valley well in May, 1914, started the first Calgary boom. Since 1941, he had been chief petroleum engineer for Home Oil, Ltd.

Alfred G. Stanley, 75, one of the founders and a stockholder in Amarillo Oil Co., died March 19 in Amarillo, Tex. He had retired from active business life 16 years ago.

John P. Murray, 69, San Angelo, Tex., oil operator who as superintendent for Sinclair Prairie Oil Co. drilled the discovery well in Teapot Dome field, in Wyoming, died March 20 in Sanderson, Tex.

George W. Hillyer, 62, Laird Hill, Tex., associated with Houston Pipe Line Co. for 22 years, died March 20 in Kilgore.

H. L. Birney, 68, business leader of the Southwest and northern Mexico who held extensive interests in producing properties near Artesia, N. M., died March 19 in El Paso.

Karl E. Barton, 58, manager of Goodyear Tire & Rubber Export Co.'s mechanical goods department, died March 21 in Akron, Ohio.

Harry Van Ness, 60, business manager for Consolidated Utilities Corp. and editor of the Petroleum Journal from 1916 to 1922, died March 25 in Wichita, Kans.

N. C. Hilton, executive manager of the abrasive wheel, diamond wheel, and bowling-ball departments of Raybestos-Manhattan, Inc., Manhattan rubber division, Passaic, N. J., died March 14 in Glen Ridge, N. J.

On this and the following three pages are presented the views of executives and technicians connected with the operation and construction of plants. The end of the war brought respite from some problems, but posed some others which the industry is solving

Present Gloomy Outlook Can Be Overcome

By C. L. HENDERSON

President, Vickers Petroleum Co.; president, Western Petroleum Refiners Association

THE present gloomy outlook for the refiner can be overcome. If the will, determination and vision so characteristic of the oil fraternity are properly applied, the difficulties now being experienced by the industry are not insurmountable.

One of the paramount problems facing the American people in all industries at present, is the apparent failure on the part of the Government to establish definite domestic and foreign policies. Until such policies are established by the federal Government, business cannot lay the solid foundations necessary to proceed with any degree of certainty. It is difficult to operate with Office of Price Administration controlling all prices and at the same time having all rationing released. There is no longer a shortage of petroleum and its products; therefore, there is no sound reason for price control now. The law of supply and demand should be the prevailing factor and, if allowed to function, would automatically produce the desired results.

Business progress is being retarded because management is unable accurately to predict the extent to which government controls are to be applied in peacetime years. Much has been said of late regarding the physical and moral aspects of the changeover from war to peace, and the plea has been made for right thinking and for respect of the rights of the individual. American industry can, if given these rights, solve many of its own problems.

It is hoped that strong leadership will eventually come to the fore, and that such legislation as is necessary will be impartial and constructive so that no industry will lack the opportunity to enjoy the benefits of its efforts.

Peacetime Possibilities of Microcrystalline Wax

By A. B. WEINGARD

President, Continental Refining Co.

THE last war initiated a new petroleum product, microcrystalline wax. MC wax, extracted from amorphous wax (crude petrolatum), either by the freezing and centrifuging method or by solvent extraction, was used extensively by the armed forces for dip-coating and ordnance wrappers, its use permitted shipping all war materials in a protective wax coat, completely protecting it against the ravages of salt water, tropical climate, etc.

Microcrystalline wax is a stable, homogeneous, non-corrosive product that withstands high temperatures without melting and sub-zero temperatures without chipping or cracking. It combines strength with toughness and flexibility, is noncaustic, odorless, and tasteless, and possesses great ductility. It can be manufactured in all colors from the natural green to snow white, depending upon its intended use.

We feel that, although born a war necessity, it has great peacetime possibilities for impregnating paper, cartons and food packages, as an absolute protection against water, moisture or odors.

C. L. HENDERSON *A. B. WEINGARD*

Postwar Effects of Refinery Wartime Construction

By A. P. FRAME

Vice President, Petroleum Advisers, Inc.

UNDER the stimulus of war, the petroleum refining industry compressed 6 or 7 years of normal technological and industrial developments into a 3-year period. This accelerated growth will have a pronounced effect not only on the petroleum industry but also on other industries. The wartime acceleration of catalytic-cracking installations has stimulated the production of higher-octane-number motor gasolines. Since V-J Day there has been in some areas an increase of eight octane numbers in gasolines and the end is not yet in sight.

General availability of high-quality gasoline will have its effect on the automotive industry, particularly in engine design. The reduction in residual-fuel-oil production, due to the substitution of catalytic for thermal cracking, will have its effect on fuel users as well as on the coal industry. The effect of wartime refinery developments is spreading to the peacetime operations of not only the petroleum but other industries.

Complex Economic Problem Faces Industry

By M. HALPERN

Vice president, The Texas Co.

THE most complex problem now facing the petroleum industry is primarily economic. In order to accomplish the opposing objectives of higher-quality products at a favorable cost to the consumer and higher wages for the worker, management will have to eliminate all nonproductive operations in manufacturing. Only the most careful scrutiny of all processes will insure economically sound operation.

The needs of peacetime are already being served by the expensive equipment installed in the war years. Promises of superior products for the American public are being fulfilled by the industry. The amazing speed with which refining facilities were converted to peaceful uses is a good index to the character of American industry. Because of the nature of modern refining equipment, such as catalytic cracking, alkylation, solvent refining, and solvent dewaxing units, conversion proceeded more rapidly than had been anticipated.

Heavy demands for middle distillates, both as finished products and charging stocks, present a problem of paramount importance. There is little doubt that the refiner will meet the demands. As a result, a greater appreciation of the middle distillate fractions will be developed.

Future Demands Effective Use of War-Born Facilities and Techniques

By M. G. PAULUS

Vice president, Standard Oil Co. (Indiana)

TODAY each refiner is coping with the problem of adapting wartime facilities to the economical production of high-quality peacetime products. Many refiners have already succeeded in adjusting operation of their new catalytic-cracking units to produce improved motor gasoline, distillate fuels, and other liquid products. Investigations of cracking catalysts and of direct processing of residual stocks via catalytic cracking are currently in progress on commercial units. Alkylation is being employed to increase the yields of higher-quality motor gasoline from crude. In certain cases refiners are already employing war facilities for new peacetime products, such as pure chemicals, improved solvents, and specialties. Other similar applications will undoubtedly be forthcoming soon.

Of greater long-range significance, however, are the intensive investigations currently in progress on applying knowledge acquired during the war to the development of new and improved processes. There are already numerous indications that this new information, frequently acquired on excursions by refiners into fields far distant from normal refining activities — synthetic rubber, atomic bombs, etc.—will soon lead to substantial improvements in refinery procedures. The full impact of these war developments on commercial refining operations will probably not be felt for several years, but the eventual result will be more efficient utilization of our petroleum reserves and production of higher-quality products than have ever before been offered.

Refining Industry Needs More Flexibility

By C. M. ALEXANDER

Vice president, Aetna Oil Co.

POSTWAR can hardly be as at present in the oil industry too little this and too much that. It surely is only an adjustment period but more extended than anticipated. Such economics can not exist long otherwise we will need to change our plans on investments and procedures.

Too much crude oil and too much gasoline with too little kerosene and too little distillates and fuel oil. If only petroleum refining had more flexibility. Put the two ends together to make the middle or stretch the middle to shorten the two ends and vice versa as desired on products yields. If such cannot be accomplished by scientific development and with economic application then the oil industry should point to less expenditures in the present direction of high-octane-gasoline yields and look to the automotive engineer for power application of petroleum products by which less refining rather than more refining would be required.

A. P. FRAME | M. HALPERN | M. G. PAULUS | C. M. ALEXANDER

W. F. SIMS | H. W. CAMP | H. O. DALE | L. H. HARVISON

Possibilities of Selective Fractionation of Gasoline

W. F. SIMS

Refinery manager, Panhandle Refining Co.

THERE are several things that the small refiner could do to improve his position in the production of leaded gasoline. One of these would be to check into the possibilities of selective fractionation of straight-run gasoline with the idea of using the lower-boiling-point material for the higher-octane gasoline and the higher-boiling-point material for the lower-octane gasoline. There are many advantages to be gained along these lines.

Another very important thing to the small refiner is the treating of the gasoline, and sometimes it is surprising at the gain in octane number that can be made by a few simple changes in the treating plant.

Peacetime Brings New Problems to Refiners

By H. W. CAMP

Manager Refining Division, Cities Service Oil Co.

DURING the war the primary aim of the petroleum refining industry was the manufacture of products for our armed forces; quality was paramount and costs, while by no means disregarded, were secondary. Now, however, the industry must operate to meet the hard facts of peacetime economics, but the growing trend toward higher octane numbers for civilian motor fuels indicates that proper recognition is not being given to the new conditions.

Many of the processes and plants utilized for aviation gasoline production during the war cannot be profitably operated for civilian motor fuel, but they must be utilized if the upward-octane-number tendency is maintained at the present rate. The current policy might be reasonable if the higher-quality fuels could be effectively used, but the average passenger car on the road is estimated to be 7 years old and the generally satisfactory wartime experience with gasolines at octane levels much below those now prevailing is proof enough that the high-octane fuels are unnecessary.

Refiners will be adversely affected by the recent increase in the price of crude without compensating increases in prices for refined products, and it seems unwise to reduce earnings still further by an unwarranted octane-number race which will reduce yields and increase operating costs.

Past Errors Can Serve as Lessons

By H. D. DALE

Vice president, Shell Oil Co., Inc.

ONE thought was driven home to me again and again last year, while I was traveling through Germany and Japan as a member of a survey for the War Department. The ruins of the oil and chemical industries in those war-ravaged countries were a fearsome reminder of what might have happened in our country. I could not help thinking that through our unpreparedness as a nation, we missed a similar fate by a very narrow margin.

Our past errors can now serve as lessons for the future. The American oil industry has a tremendous responsibility to develop and apply new and better products through aggressive, long-range research. The resulting new developments will be of inestimable value to our armed forces.

Concomitant with this responsibility is the need for the closest exchange of information and help between the oil industry and the Government where national defense is involved. The lack of awareness of military demands which preceded the recent war resulted inevitably in certain confusions in implementing necessary Government-industry teamwork in the early part of the war. Should we ever be forced into war again we will not have 2 years to eliminate red tape and production road blocks. We may not even have 2 hours. Atomic weapons and guided missiles demand that we stay far in front in technical achievements.

Improved Methods of Handling Low-Octane Naphthas Promised

By L. H. HARVISON

Vice President, The M. W. Kellogg Co.

ONE of the vital problems facing the refiner in meeting the new quality standards for motor gasoline, is that of increasing the octane rating of naphthas. With the probability that gasoline standards may go even higher, it is essential that the problem be solved by most refiners in the near future. Present data indicate that the only available method of raising these naphthas to the required octane level will be through the use of a catalytic process.

Catalytic hydroforming is currently producing the desired quality of high-octane naphthas and is capable of meeting quality standards. Yields are both adequate in quantity and superior in quality to other methods.

Continuous efforts are being directed toward reduction of manufacturing costs through modification of present operating conditions and improvements in catalysts and plant design.

Should these efforts prove to be as successful as hoped, the results may stand among the most significant developments of 1946—providing refiners, through improved catalytic hydroforming, with a more economic method of processing low-quality naphthas to meet future octane standards.

European Industry Must Be Rehabilitated

By H. S. BROWN
President, Foster Wheeler Corp.

OUTSTANDING, of course, in the world's industrial picture is the necessity, I might say the urgent necessity, for the rehabilitation of industry in those countries in Europe, Asia, and Africa which were the battlefields of the war. In our own country, a great surplus of buying power now in the hands of the public is waiting to be spent reasonably in the purchase of needed consumer goods. These two major demand factors, now pressing for satisfaction, will require a tremendous amount of engineering and construction, probably as great as that accomplished during the war. I personally am very hopeful for the future and when the labor problem is straightened out to the satisfaction of all parties concerned, I believe the demand for heavy industrial equipment will accelerate to a very high peak.

Technical Research Looks Forward

By M. W. BOYER
Vice President, Standard Oil Co. of New Jersey

THE foremost reconversion problem facing refinery operators is the shift from petroleum products for war to petroleum products for peace. Now that we are again able to consider the civilian market, technical research looks forward to expanding into an almost limitless field. New laboratories and facilities are being planned. Standard Oil Development Co., our own technical organization, is spending almost $8,000,000 to build two new research centers. The immediate trend will be toward utilizing war-developed products for civilian use. New gasolines, motor oils, industrial lubricants, process oils, and corrosion preventives will soon be forthcoming.

Later on, as the oil industry refills its war-depleted storehouse of scientific knowledge and obtains newly trained men research will be directed even more intensively toward the commercial production of liquid hydrocarbons from natural gas, coal, and oil shale.

The fields of physics, plastics, manufactured rubber, and new industrial materials are also logical roads which the oil industry will explore.

Unrealistic Price Ceilings a Deterrent

By W. F. BURT
Vice President, Socony-Vacuum Oil Co., Inc.

THE industry seems to be agreed that the demand for kerosene and middle distillates will increase more rapidly than the demand for gasoline. In 1946 the domestic demand for gasoline will be less than in 1941, while the demand for middle distillates and residual fuel oil will be substantially greater. Temporarily the industry seems to be overbuilt from the standpoint of cracking facilities for producing gasoline and, with reduction in cracking operations to fit the gasoline demand, the trend to higher octane levels can only be maintained at increased expense, e.g. by more intensive reforming.

The refiner with catalytic-cracking facilities will have an especially advantageous position if the industry must depend more and more on crudes of the West Texas type, kerosene availability will decrease unless more expensive refining methods are adopted which would call for higher prices. These shifting demands can undoubtedly be met in a free market, and if price control is maintained it is to be hoped that shortages will not develop as a result of unrealistic price ceilings for the various commodities. If more bunker fuel must be supplied, the price should be such as to justify the running of additional crude to meet this demand.

Small Refineries Profiting From Scientific Research

By D. W. HARRIS
President, Universal Oil Products Co.

RESEARCH in the petroleum industry has been given new impetus since 1941. Research was largely responsible for the production of 100-octane aviation gasoline for the armed forces of the United Nations, and for the components which were urgently needed to produce synthetic rubber.

The large oil companies have invested millions of dollars in research activities and are now engaged in a program of expansion in this direction. Only with new processes and new techniques, developed through scientific research, can the independent small refiner continue producing and marketing his product profitably during the competitive years ahead.

Many of the smaller refiners have acknowledged the worth of independent research organizations and are profiting materially from the knowledge and facilities available through these highly specialized groups.

The trend is definitely toward more and better research—the fundamental basis for production of high quality petroleum products.

SPECIAL REFINING SECTION

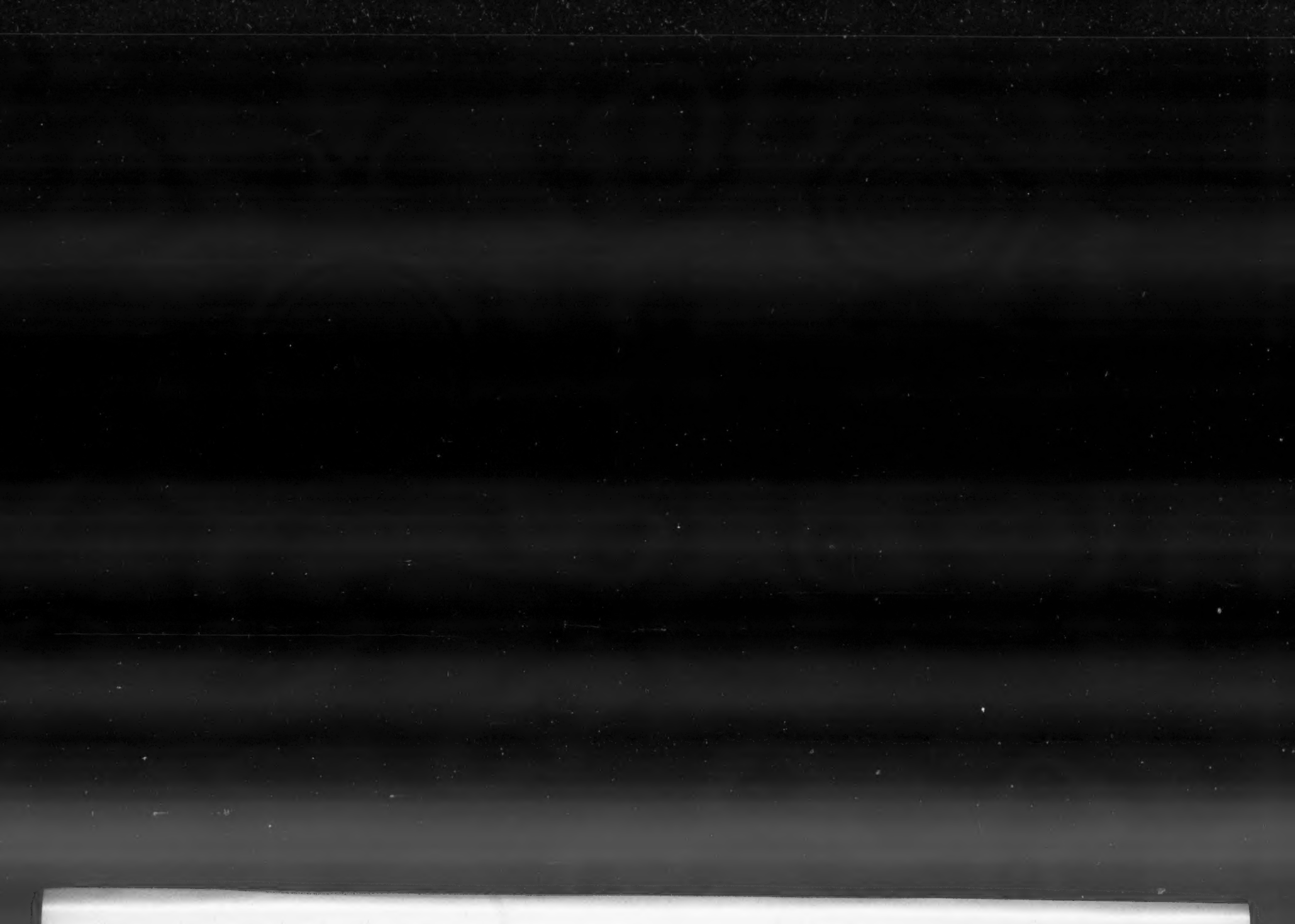
BEGINNING on the following page is a 32-page multicolor section, which contains a graphic presentation of the most important catalytic refining processes which constitute the backbone of future design and construction. Following this section are presented 40 pages of engineering and operating articles pertaining to refining, and a complete plant survey, showing companies, plant locations, and refining capacities.

H. S. BROWN

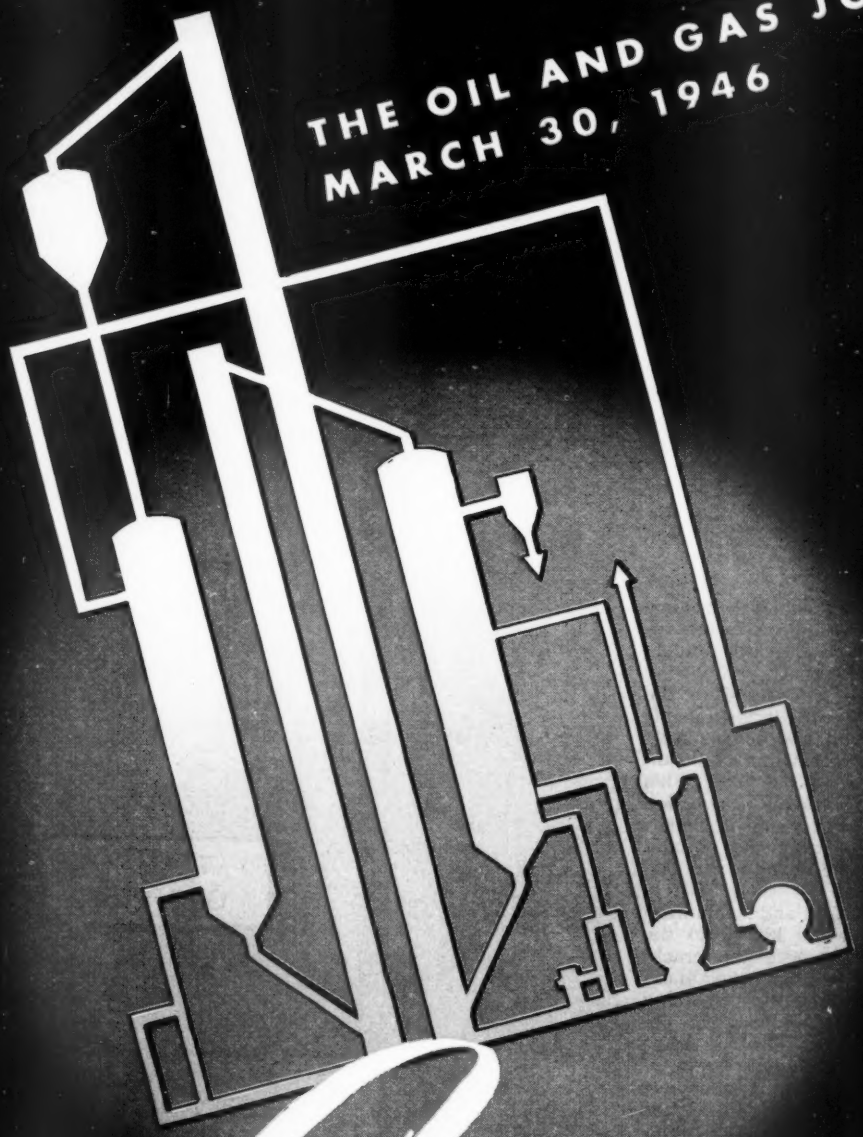
M. W. BOYER

W. F. BURT

D. W. HARRIS



THE OIL AND GAS JOURNAL
MARCH 30, 1946



Catalytic REFINING

cycloversion

CYCLOVERSION has, in the last year, taken on a broader process aspect than strictly that of a catalytic cracking process. The flexibility inherent in the process has been more thoroughly explored, particularly, the reforming and the combination reforming and cracking aspects of the process.

Operation

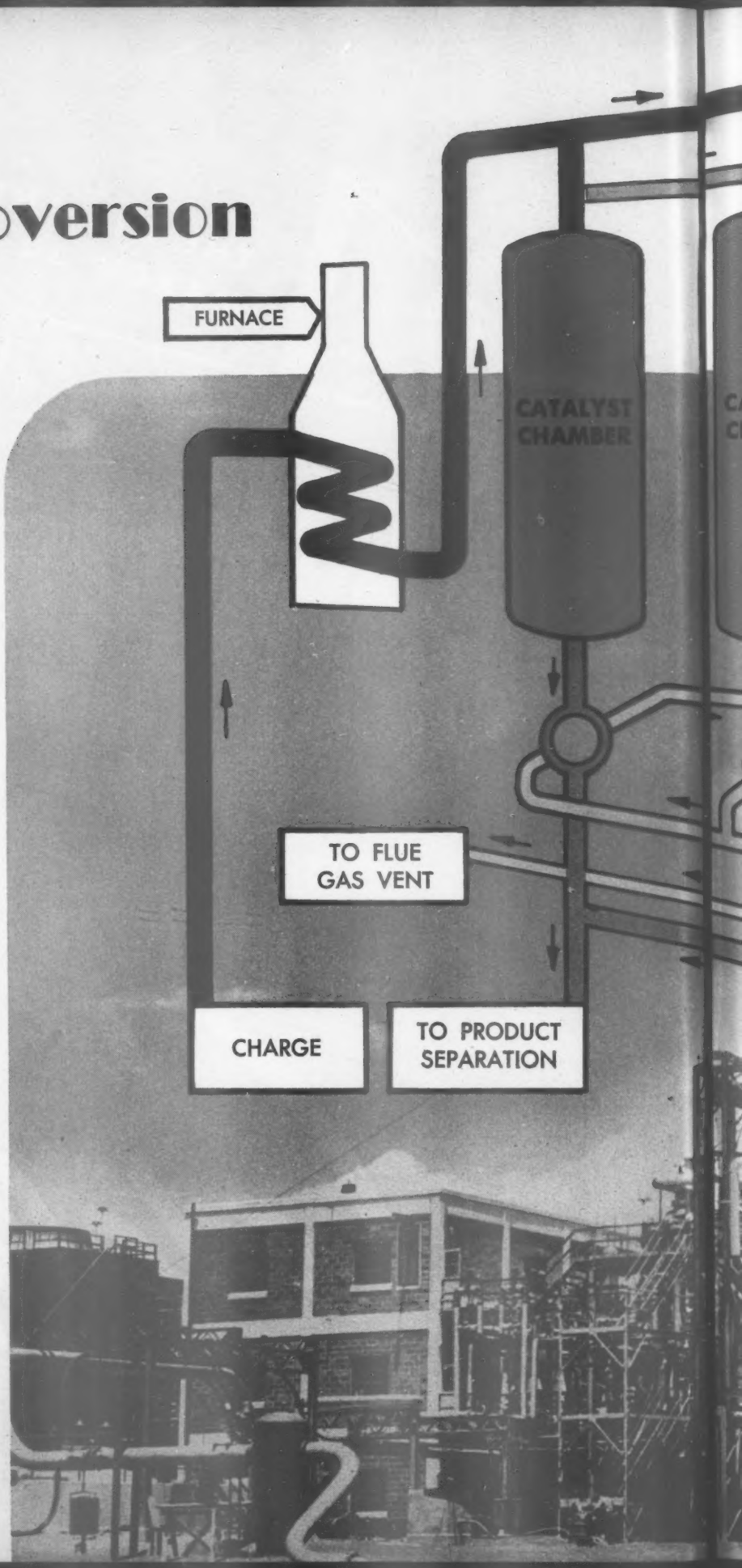
Reference to the accompanying flow diagram and a review of the operation will assist in a clearer understanding of the process.

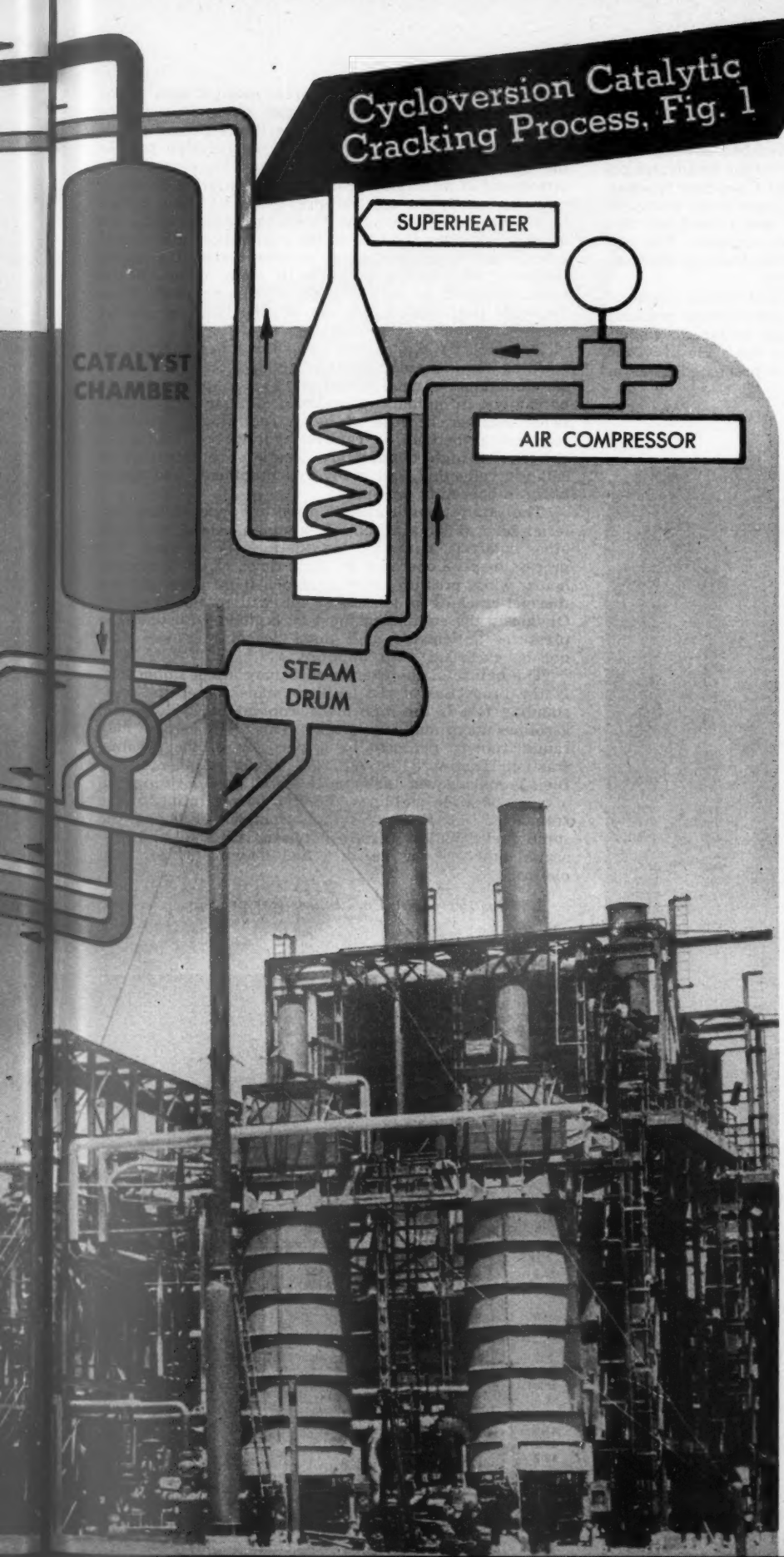
The fresh feed is charged to the process furnace where it is preheated to enter the catalyst bed at 980°-1,000° F. A small amount of steam diluent is added to the feed. This diluent is added to the convection bank in the form of steam or water. It assists in vaporizing the oil and increases the octane rating of the gasoline.

The superheated oil and steam mixture passes from the heater to the catalyst chamber where the cracking or reforming reaction takes place. The catalyst chambers are operated at about 85 psi. and the reaction period ranges from 2 to 10 hours when cracking and up to 24 hours when reforming. From the reaction chambers the catalytic product flows to the waste heat exchanger for the recovery of heat through the production of steam. From the waste heat exchanger the product passes to heat-exchange and condensing equipment, and on to the vapor-oil-water separator. The condensed water is drawn off at this point, the vapors going to absorption and vapor recovery unit and the hydrocarbon condensate to fractionation.

In addition to the waste heat exchangers, the steam system consists of a steam drum and other necessary auxiliaries. The steam produced on the unit is used principally in catalyst regeneration, and a unit may be designed to be self-sufficient with respect to steam.

In the regeneration period, steam from the waste heat exchanger is superheated to 850° F. The steam is then mixed with air and is fed to the catalyst chamber being regenerated.





This mixture burns the carbon off the catalyst restoring it to approximately 100 per cent of original cracking efficiency. The temperature in the regeneration period is controlled at about 1,350°-1,400° F. by regulating the amount of air in the regeneration gases. The use of a high regeneration temperature and steam diluent results in considerable water gas reaction thereby reducing the amount of air required. Before passing to the vent stack the spent combustion gases pass through the waste heat exchanger; thus steam is produced in both the process and regeneration periods.

A review of yields and octanes obtainable through Cycloversion may best be discussed with the aid of Tables 1 and 2.

Cycloversion Cracking

Table 1 covers Cycloversion of a light (36.5° A.P.I.) gravity Panhandle gas oil at two conversion levels.

It will be noted that with this gas oil little change is experienced in the quality of product with the deeper conversion level. The principal difference being the greater volume of catalytic gasoline with attendant greater gas production and carbon deposition.

Cycloversion Reforming

Table 2 presents inspection data on several low-loss reforming runs. The reformed gasoline shows an average appreciation of 13 octane points at the 3 cc. TEL level, with an average of 95 volume per cent recovery of C_4 to 400 e.p. gasoline. Carbon deposition is of the magnitude of 0.4 to 0.6 weight per cent of charge for a 24-hour process cycle when handling feed of the approximate characteristics of the three naphthas shown in Table 2.

The catalytic treatment of a blend of gas oil and naphtha has been investigated with quite promising results. Octanes of 5 to 6 points higher are obtained through charging such a mixture than are obtained by blending the products of blocked catalytic naphtha reforming and catalytic gas oil cracking operations. Not only are

the octanes higher, but the yield of catalytic gasoline is also about 2.5 volume per cent greater than is obtainable through separate processing.

The Cycloversion process is a fixed-bed development, and is planned to eliminate or minimize the disadvantages both of the moving catalyst and the fixed-bed types of process. In general design it corresponds more nearly to the older Houdry process. That is, it uses a fixed-bed idea for the catalyst, located in a reaction chamber. The catalyst is regenerated in place, but other features differentiate it widely from the earlier process.

The provision for cooling the catalyst during regeneration or for heating it during the endothermic cracking reaction differs from other processes so far developed. During the cracking reaction part of the cycle provision is made to introduce either steam or preheated gases or vapors into or between the different catalyst beds in the reactor in such amounts and at such temperatures as to maintain the reaction mass at the desired temperature for cracking. Similarly, during the regeneration part of the cycle cold gases or steam at low temperatures is introduced at intervals to control the maximum temperature reached by the catalyst, preventing its being heated to a temperature damaging to its catalytic activity. As in other processes the heat in the combustion and diluent gases is used to preheat charge or other material, generate steam or any similar purpose. In many cases all the steam required in such a process may be made from its waste heat, saving the use of other fuel of greater utility or value.

Designers of the process as applied to conventional cracking requirements claim advantages such as practical elimination of catalyst loss due to fines as are formed by catalyst in motion; no tendency to bond catalyst particles together because of heavy, nonvolatile products condensing thereon, as catalyst-hydrocarbon contact is entirely in high temperature locations; elimination of catalyst collecting and recovery equipment, and flexibility in operating pressures.

The catalysts used include a natural type of clay material such as bauxite (chiefly alumina, Al_2O_3), although other catalysts, natural or synthetic, may be used. The process may be operated on cycle times of up to several hours, while pressures may approach those used in some thermal-cracking processes, at the will of the operator. Obviously the equipment must be built to withstand the pressures anticipated, and these design pressures may not be exceeded with impunity.

The nature of the charge stock may affect importantly the properties of the gasoline made therefrom. Outstanding fact is the high olefin content of Cycloversion gasolines under normal operation. This olefin content may range from 65 per cent to 88 per cent of the gasoline fraction. Therefore the A.S.T.M. octane rating of these fuels is much lower than the Research or C-1 ratings; in a group of seven gasolines, A.S.T.M. octane ratings range from 75 to 80.1; Research ratings from 86.1 to 94.8 on the same fuels. Widest spread between A.S.T.M. and Research numbers was 16, in a fuel showing 88 per cent olefins.

Phillips Petroleum Co. licenses this process.

TABLE 1—CYCLOVERSION OPERATION—CHARGING TEXAS PANHANDLE GAS OIL

Conversion, single pass, vol. %	50.5	62.9
Temperature, °F.	984	1,010
Pressure, psig.	75	85
Process period, hours	10	4
Yields, per cent of charge:		
Catalytic gasoline, 400 e.p., vol. %*	39.7	45.2
Propylenes, vol. %	3.3	5.4
Butylenes, vol. %	4.2	6.0
Catalytic recycle, 400+, vol. %	49.5	37.1
Gas, f.o.e., vol. %	9.0	12.9
Carbon, wt. %	1.7	2.6
Inspection tests:		
Feed:		
Gravity, °A.P.I.	36.5	36.6
Distillation:		
10%	472	510
90%	735	717
Aniline No.	186	182
Catalytic gasoline:		
Gravity, °A.P.I.	60.3	60.3
Reid vapor pressure	10.0	10.3
A.S.T.M. octane No.	77.0	76.3
+3 cc. TEL	91.0	92.9
Research octane No.	86.8	86.2
+3 cc. TEL	92.1	93.1

*Includes butanes.

TABLE 2—CYCLOVERSION OPERATION — CHARGING STRAIGHTRUN NAPHTHA

	Pennsylvania		Mid-Continent		West Texas	
Naphtha source						
Temperature, °F.	1,015		990		1,015	
Pressure, psig.	50		15		50	
Process period, hours	24		15		24	
Yields, vol. % of charge:						
Catalytic gasoline, C_5, 400 e.p.	92.9		88.0		85.0	
Dry gas, f.o.e.	6.4		9.2		5.4	
Inspection tests:	Feed	Catalytic gasoline	Feed	Catalytic gasoline	Feed	Catalytic gasoline
Reid vapor pressure	3.5	10.2	4.0	10.1	2.6	8.3
Gravity, °A.P.I.	62.2	62.8	59.0	59.0	54.8	55.1
Total sulfur, wt. %	0.055	0.005	0.037	0.006	0.140	0.008
Distillation:						
I.b.p.	100	88	121	98	144	100
10%	156	137	189	165	196	165
50%	252	248	254	250	258	245
90%	353	343	321	325	343	331
End point	404	409	366	377	394	406
A.S.T.M. octane No.	48.8	61.5	41.1	55.9	56.5	66.5
+1 cc. TEL	57.3	71.0	53.5	68.2	63.5	77.5
+3 cc. TEL	67.1	79.6	67.0	78.4	70.0	83.1
Research octane No.	49.6	65.2	....	....	58.1	74.3
+1 cc. TEL	57.9	74.4	....	....	66.0	83.2
+3 cc. TEL	66.7	80.5	....	....	72.1	88.4

Fluid

Fluid Catalytic Cracking Process, Fig. 1

THE so-called Fluid catalytic-cracking process was developed in great measure to eliminate some of the inherent disadvantages of the fixed-bed system which had been developed earlier. Another reason was to improve the contact efficiency between charge vapors—or liquids—and catalyst surface, to give greater flexibility in throughput and variation of operating conditions. Obviously fluid operation has some disadvantages of its own which have been overcome essentially in commercial practice. This process was developed largely

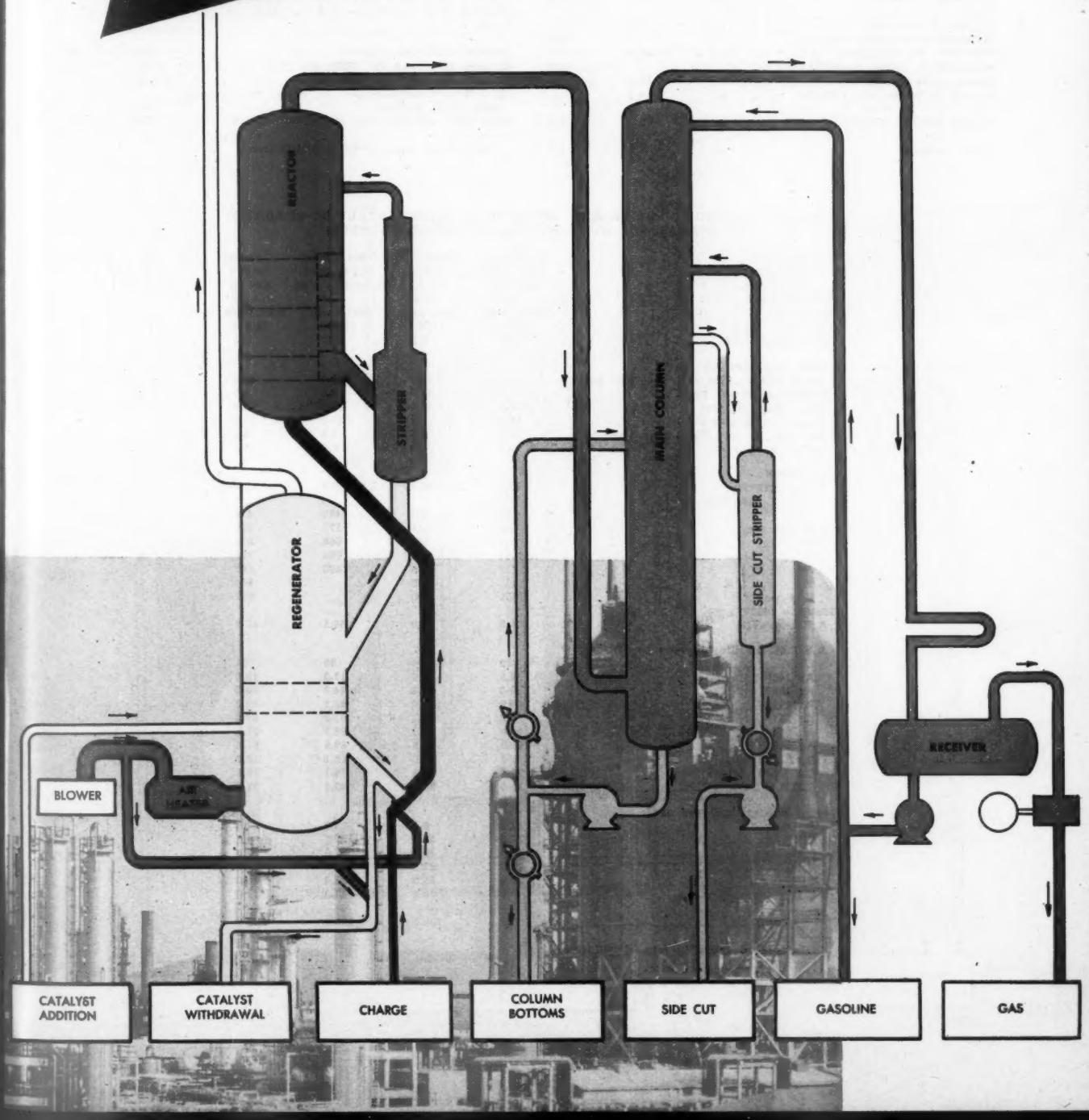


TABLE 1—PRODUCT YIELDS IN NORMAL OPERATION WITH SYNTHETIC FLUID CATALYST

Feed stock—	Light mixed gas oil	Heavy mixed gas oil	Cracked gasoline
Type operation	Max. butylene	Max. butylene	Retreat
Reaction temperature, °F.	935	945	875
Fresh feed, BPCD	20,500	16,620	14,680
Slurry oil, BPCD	500	.....	1,200
Total feed, BPCD	21,000	16,620	15,880
Product yields, per cent:			
Butylenes, volume	7.0	10.7	2.3
Isobutane, volume	6.4	6.9	4.0
n-Butane, volume	0.9	1.5	0.7
C_5-150° F., volume	11.5	16.7	...
Aviation-base stock, volume	...	...	48.1
150°-475° F., volume	36.7	29.8	...
340°-400° F. motor naphtha (vol.)	...	...	12.9
Light cycle gas oil	29.1	13.5	20.0
Heavy cycle gas oil, volume	1.9	14.9	...
C_3 and lighter, weight	9.5	12.8	6.9
Coke, weight	4.1	6.3	6.7

TABLE 2—PRODUCT PROPERTIES FROM NORMAL OPERATION WITH SYNTHETIC CATALYST

Feed or product—	Light G.O. feed	Heavy G.O. feed	Retreat feed	Aviation base	Motor naphtha
A.P.I.	37.6	26.4	41.5	46.0	39.5
A.S.T.M. distillation:					
I.b.p.	380	525	175	126	360
10 per cent	454	698	239	190	366
30	504	750	293	232	369
50	545	790	354	263	373
70	579	880	400	288	378
90	619	1,040	445	308	392
End point	648	...	488	335	420
Aniline point, °F.	168	200	...	20	88
A.S.T.M. pour (max.), °F.	10	100	...	...	...
W. & N. char. factor	11.8	11.9	...	...	...
R.v.p.				3.0	...
Octane, A.S.T.M. (clear)				82.0	56
Octane, 1C + 4.6 cc. TEL/gal.				94.5	...
Octane, 3C + 4.6 cc. TEL/gal				S+3.5	...
1C + 4.6 cc. blended to 7 lb. R.v.p. with isopentane (95% purity)				98.0	...
Vol. % C_4 alkylate req. in 100-oct. blend				20.0	...

*Calculated from 10 mm. distillation.

TABLE 3—PRODUCT YIELDS AND INSPECTIONS FROM CATALYTIC-CRACKING OPERATIONS WITH NATURAL (CLAY) CATALYSTS

Feed stock—	Paraffinic wide-cut gas oil	Paraffinic light gas oil	East Texas 50 per cent reduced crude	Coastal heavy gas oil
Operation No.	7	8 A	9	10
Operation	Mot. gaso.	Mot. gaso.	Mot. gaso.	Mot. gaso.
Feed-rate, BPD	20,000	21,500	16,000	22,000
Temperature, °F.	910	875	930	930
Yields, per cent on feed:				
10 lb. R.v.p., 400° e.p. gasoline, vol.	48.0	42.5	43.3	50.0
Excess butanes, vol.	7.8	11.5	7.5	6.0
No. 2 fuel oil, vol.	31.0	39.0	28.0	29.0
Heavy cycle gas oil, vol.	10.0	5.0	17.0	12.5
Dry gas (C_3 and lighter), weight	6.6	6.8	6.4	6.4
Coke, weight	5.7	5.0	6.8	4.2
Feed stock:				
A.P.I. gravity	31.0	33.5	25.5	22.0
A.S.T.M. distillation:	(*)		(*)	(*)
I.b.p.	450	480	480	478
10 per cent	540	556	575	570
30	624	580	666	632
50	681	601	766	702
70	742	625	890	787
90	861	659	...	894
End point	965	700	...	972
Gasoline (400° e.p.):				
A.P.I. gravity	60.0	61.0	58.5	57.0
A.S.T.M. distillation (per cent):				
I.b.p.	99	94	99	101
At 140°	14.5	25.0	17.0	13.0
At 158°	22.0	35.5	24.0	20.0
At 212°	43.0	58.0	45.5	40.0
At 257°	59.0	68.0	61.0	57.0
At 294°	68.0	84.5	69.5	68.0
At 356°	89.8	92.0	89.5	91.0
R.v.p.	9.9	10.0	10.1	10.0
C.F.R.-M. (clear)	80.5	81.3	79.1	80.5
C.F.R.-F.	92.0	94.0	93.8	92.9
C_3 and lighter, mol per cent:				
H_2	12.0	8.0	23.0	12.0
CH_4	30.0	11.0	23.0	34.0
C_2H_4	10.0	10.0	7.0	7.0
C_2H_6	19.0	26.0	13.0	14.0
C_3H_6	22.0	35.0	24.0	22.0
C_3H_8	9.0	10.0	10.0	11.0
Total	100.0	100.0	100.0	100.0

*Calculated from 10 mm. distillation.

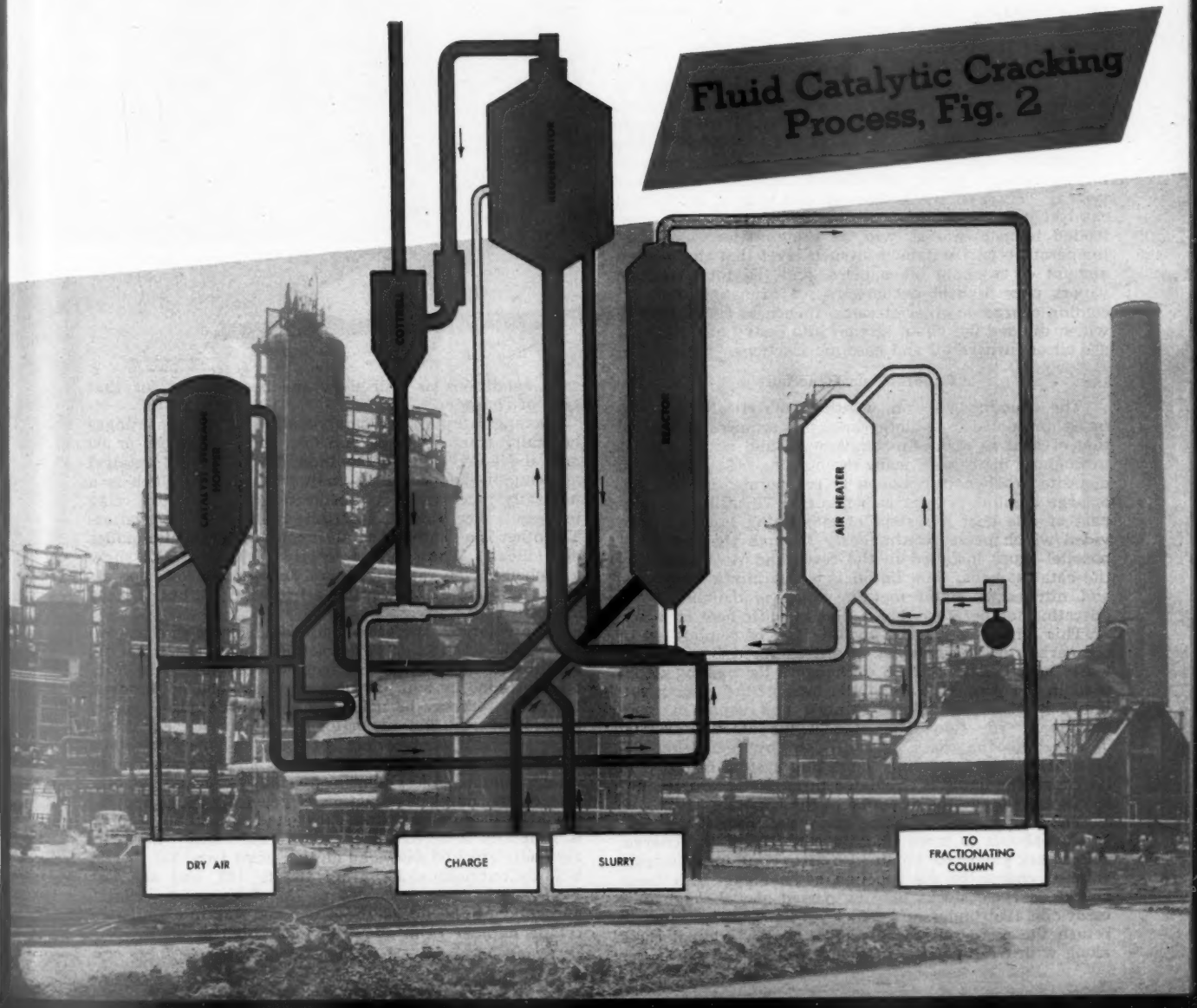
immediately prior to the outbreak of World War 2 and now has more than 30 units operating or in standby status.

The principle of the process is to bring hot charge vapors to be cracked into intimate contact with a finely divided natural or synthetic catalyst to effect the cracking reaction. The earlier units, developed and designed under the extreme stress of war demands, are huge stills more than 200 ft. in height, their operation typified by the first flow chart shown here. Briefly, charge stock is vaporized in a tube still and is forced into the large pipe leading to the reaction vessel. En route to the reaction chamber the vapors are mixed with catalyst of up to 300-mesh size, which previously has been heated to 1,000° F. or higher, and the residual heat in which raises the oil vapors to the cracking temperature of 900° F. or higher or lower, depending on the results desired, the activity of the catalyst, and the refractivity of the charge. In the reaction chamber the cracking operation is completed, the catalyst in greater part settles out of the vapor stream and passes along with a blast of air to the regenerator wherein the carbon deposited on the catalyst is burned off; the decarbonized catalyst settles to the bottom of the regenerator which serves as a hopper. From this hopper section it gravitates to rejoin the charge vapors and repeat the cycle. Catalyst may circulate in a large unit at the rate of 200-300 tons per hour, or even more.

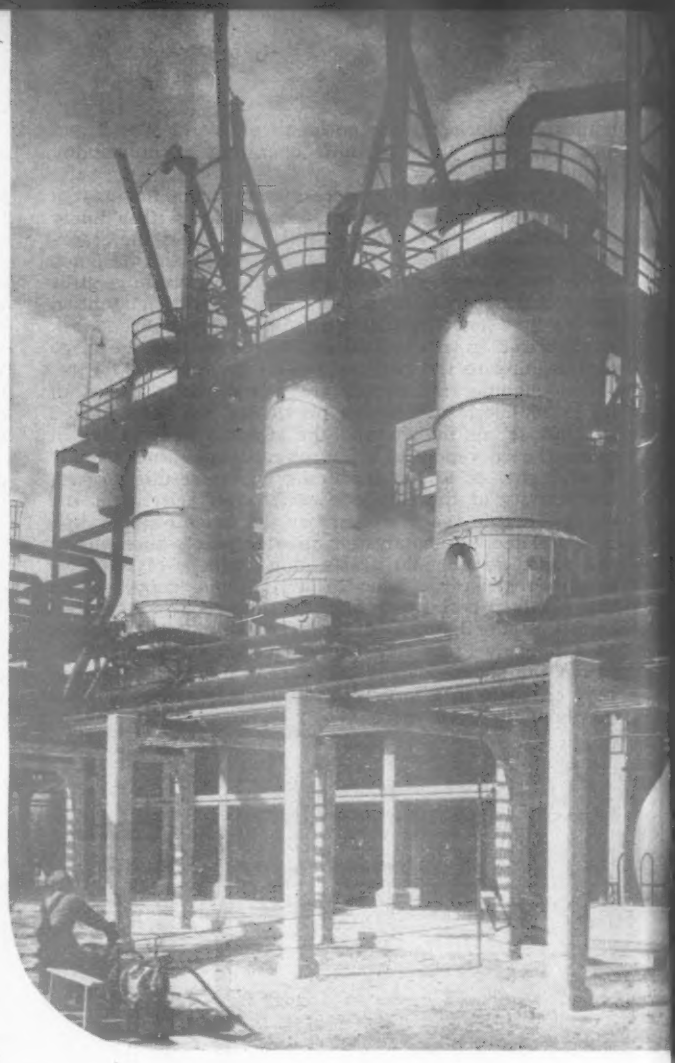
The vapor cracked in the reactor, along with small amounts of fine-particled catalyst, passes to the precipitator in which most of the entrained catalyst is removed by means of a Cottrell electrical precipitator and may be returned to the main hopper or an auxiliary catalyst container, when it rejoins the cycle. The charge vapors, still containing small amounts of catalyst, pass to the fractionator from the overhead of which is taken the cracked-gasoline fraction. From the tower side one or more streams of catalytic gas oil or furnace oil is or may be taken, for recycle to the unit for use for other purposes as indicated. From the tower bottom the heaviest of the uncracked stock, which contains the catalyst carried over, is returned as a slurry to the cracking cycle to reenter the reaction zone and return to the regenerator.

The second flow chart shown here is the more modern design for application especially in smaller capacity units of down to 2,000 bbl. per day of charge. Construction and operation have been simplified and the amounts of steel and other fabricated material have been reduced importantly. A unit for this design to process some 3,000 bbl. per day of charge has been contracted for recently. Yields and properties of products from Fluid cracking are shown in the accompanying tables. Note that up to 50 per cent of motor gasoline is produced; about the same amount of aviation fuel may be made, with 10-15 per cent of heavy motor naphtha.

Universal Oil Products Co. licenses the process.



houdry



THE Houdry process is the pioneer in commercial catalytic cracking and until after the start of World War 2 was the only process with any appreciable amount of commercial capacity in operation. It belongs to the fixed-bed type of process. Catalyst, which may be either a synthetic, metal silicate or oxide type or a natural metal silicate type, is housed in a series of beds superimposed above one another in a catalyst container generally termed a "catalyst case."

Charge stock is brought into contact with the catalyst generally in vapor form at predetermined temperatures sufficiently high to maintain the mass at the desired temperature for the desired cracking. Normally three or more such cases are provided for each unit. When the catalyst is covered with carbon deposit sufficiently to reduce its activity below some given value, it is regenerated by introduction of air-flue gas mixture to burn off the carbon and revivify the catalyst. Charge is introduced into the cases alternately; in each set of three cases one is reacting charge to form motor fuel or aviation-fuel components; one is undergoing the carbon burning cycle and the third is being swept clear of flue gases preparatory to be placed on stream again.

In operating the process, topped crude is heated in a still and such portion vaporized as may be desired. The vapors are led to the catalyst case which is on stream, at temperatures which may be varied somewhat widely for different stocks or to suit different operating requirements, but for which 850°-900° F. may be considered typical. The vapors pass through the beds of granulated catalyst under conditions of relatively carefully controlled temperature as will be shown later. This case temperature is maintained at such level that the desired amount of cracking takes place, and the total reaction vapors pass to heat exchangers for exchange with incoming charge or other streams, thence to a fractionator which divides the vapor stream into heavy gas oil, light gas oil or furnace oil and gasoline fractions.

Endothermic Reaction

The cracking reaction, whether catalytically or thermally promoted is endothermic and requires the addition of heat to maintain temperature and reaction rates throughout the cases. During the burning-off period when deposited carbon is removed to regenerate the catalyst, a large amount of heat is generated. To utilize at least part of this heat a system of circulating liquid is provided which passes continuously through the system of parallel pipes installed in the cases and surrounded by the catalyst beds. This liquid is a salt mixture, nitrates and nitrites of alkali metals, which is molten at the operating temperature, has a high specific heat capacity.

This mixture is heated by the heat of combustion of the carbon on the catalyst, gives up part of its heat in waste heat boilers or heat exchangers for making steam used in the process. Part of the heat in the cooling salt liquid is given up to the catalyst and vapor in cases on stream; the flow, and with it the amount of heat delivered to the cases, is controlled by regulating the amount of liquid entering the piping system installed in the cases. The liquid is circulated through the case in countercurrent flow to the direction of the vapors.

Yields of cracked gasoline may vary from 40 per cent or thereabouts to more than 60 per cent of the charge. The higher yields are obtained by recycling insufficiently cracked charge to the reaction cases along with fresh charge. Recycle stocks may be passed also through new cases operated under different conditions, rather than to return the more refractory recycle to the original cases along with fresh charge, to permit control of each under such conditions as will show the best results for that type of charge.

Octane rating of the catalytically cracked fuel ranges normally from 76 to 80 A.S.T.M. motor method, or 90 and above by C.F.R.-C_3 method. Two types of catalyst are employed, one a clay "natural" catalyst which is a naturally occurring hydrosilicate of aluminum clay processed according to a definite method of preparation. The other is a synthetic catalyst composed of metal oxides and silicates. The synthetic catalyst is reported to show a higher octane rating product under analogous operating conditions, and generally a higher yield, but is more expensive in first cost.

The catalytic operation may yield either one gas oil or recycle fraction or two fractions, one light from the tower side, the other heavy from the bottom of the fractionator. One or both of these may be recycled, cracked thermally, or may be marketed as furnace oils or diesel fuels, industrial fuel oils or for other purposes. For diesel fuels the light furnace oils (gas oils) show lower cetane number than do virgin stocks, but the degradation of cetane number is less than in thermally cracked gas oils. The cetane number reduction is generally from 5 to as much as 10 numbers, from most stocks. Aniline number is generally lowered also; a California stock when catalytically cracked shows an aniline point from 135 to 113; a Mid-Continent stock, from 189 to 165, and an East Texas stock drops from 166 to 137. From most paraffin and mixed-base stocks these cracked gas oils range in cetane number from about 40 to as high as 55.

Houdry Process Corp. licenses the process.

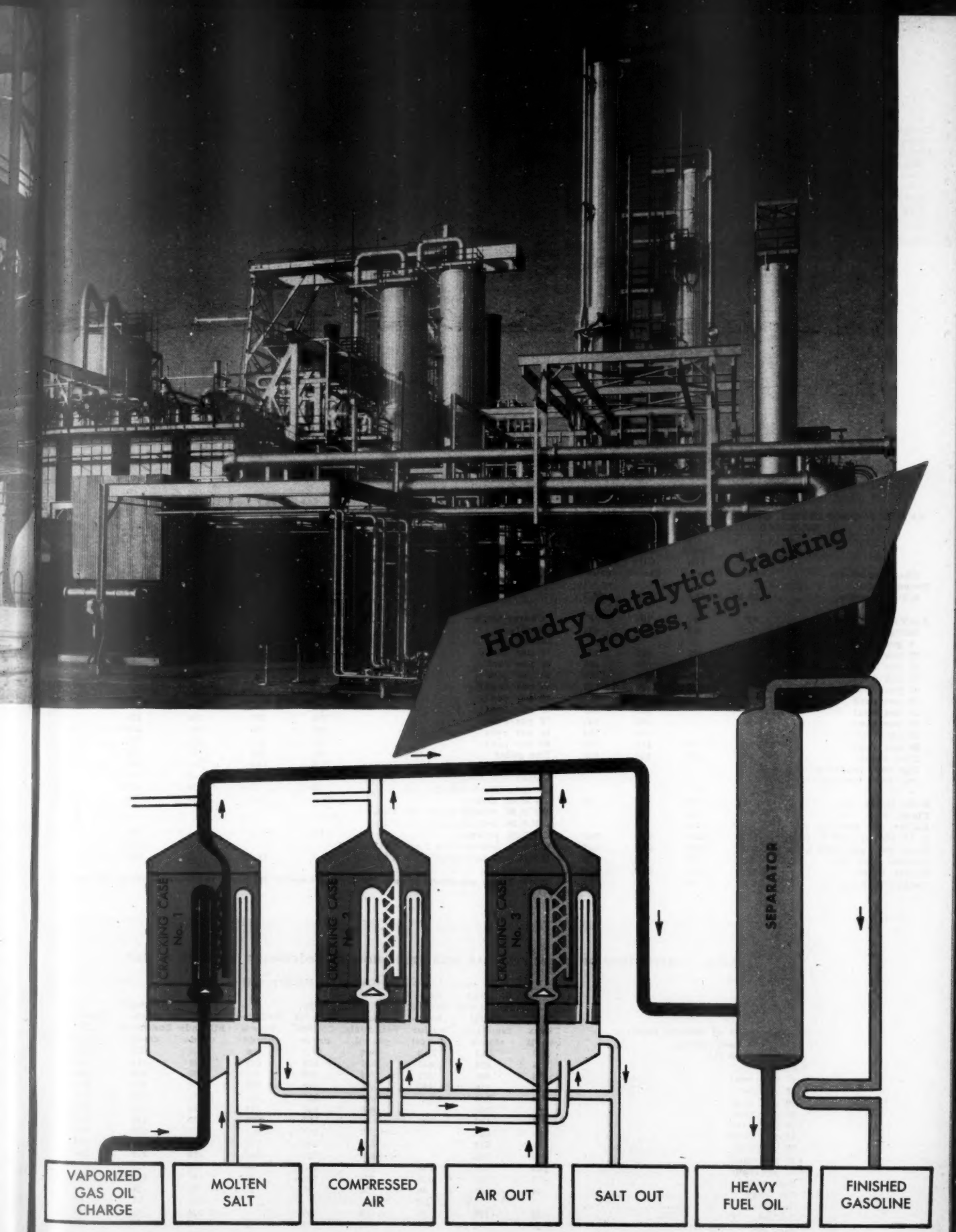

Houdry Catalytic Cracking Process, Fig. 1
CRACKING CASE No. 1
CRACKING CASE No. 2
CRACKING CASE No. 3
SEPARATOR
VAPORIZED GAS OIL CHARGE
MOLTEN SALT
COMPRESSED AIR
AIR OUT
SALT OUT
HEAVY FUEL OIL
FINISHED GASOLINE

TABLE 1—TYPICAL YIELDS AND INSPECTIONS OF PRODUCTS FROM HOUDRY FIXED-BED OPERATIONS

Type charge stock: Gas oil from mixed-base type crude
Type catalyst: Synthetic
Type process: Once-through cracking for motor-gasoline production

	Vol. % fresh charge to reactor	Gravity °A.P.I.	A.S.T.M. distillation, °F. 5%	10%	50%	90%	95%	R.v.p. (psi.)	C.F.R.M. clear octane	Bayholt color
Charge:										
Virgin gas oil	100.0	35.2	490	506	540	672	710	...	...	...
Products:										
Motor gasoline	46.3	57.9	115	127	232	368	...	9.9	78.9	30
Catalytic No. 2 fuel oil	39.8	22.5	479	490	520	590	610	...	...	...
Catalytic heavy gas oil	5.9	19.0	588	600	650	710	...	...	...	...
Excess C_4 fraction	3.9	...	...	...	...	...	...	...	...	...
Dry gas (C_2 and lighter), wt. %	4.3	...	...	...	...	...	...	...	...	...

TABLE 2—COMPOSITION OF HOUDRY GASOLINE PRODUCED BY CRACKING EAST TEXAS GAS OIL

Cut No.	Boiling range, °F.	Cut volume per cent of gasoline	Analysis of cut (volume per cent of cut) Naphthene	Olefin	Paraffin	Aromatic
1	Below 50	6.3	0.0	15.0	85.0	0.0
2	50-104	11.5	0.0	7.5	92.4	0.0
3	104-156	11.9	19.7	7.5	77.8	0.0
4	156-212	11.2	40.3	7.0	47.7	0.0
5	212-257	9.9	37.2	6.3	32.8	5.8
6	257-302	12.9	30.6	9.7	23.2	23.7
7	302-347	15.8	27.0	2.5	26.0	42.5
8	347-392	15.3	39.9	1.8	21.1	44.5
	Per cent of total gasoline	100.0	25.6	5.6	48.3	37.2
						22.5

TABLE 3—PROPERTIES OF HOUDRY CATALYTICALLY CRACKED FUEL OILS

Charging stocks—	Frio County crude	Healdton gas oil	Oklahoma City gas oil	Pennsylvania crude
Properties:				
A.P.I. gravity	25.6	32.9	32.8	38.7
A.S.T.M. distillation:	°F.	°F.	°F.	°F.
Initial	437	468	488	435
5 per cent	...	...	...	...
10 per cent	506	496	487	472
20 per cent	...	...	500	485
30 per cent	...	...	510	497
40 per cent	...	...	524	508
50 per cent	...	...	536	520
60 per cent	...	...	551	532
70 per cent	...	...	566	546
80 per cent	...	...	586	568
90 per cent	620	594	611	599
End point	646	620	634	652
Per cent recovery	...	...	...	...
Per cent residue	...	...	...	...
Pour point, °F.	15	15	15	10
Flash, P.M., °F.	154	220	...	...
Sulfur, per cent by wt.	1.17	0.40	...	...
S. U. vis. at 100° F. (sec.)	38.0	38.0	39.0	39.0
Carb. res., per cent by wt.	0.02	0.07	0.09	0.12
Aniline No., °F.	114	150	146	160
Diesel index	29.2	49.3	47.9	62.0
Cetane number	40	52	55	62

TABLE 4—HOUDRY STABILIZED MOTOR GASOLINE

Charge stock—	East Texas, Rodessa and coastal pressure-still stock		California high-sulfur fuel	Illinois reduced crude	E. Texas gas oil
Gravity	61.7	59.6	55.7	56.8	64.0
Initial	90	92	95	79	86
10 per cent	122	123	129	125	112
20 per cent	141	145	156	157	130
30 per cent	162	168	186	185	141
40 per cent	184	194	215	216	160
50 per cent	208	219	244	245	209
60 per cent	236	244	279	274	238
70 per cent	270	273	308	304	268
80 per cent	306	304	340	329	302
90 per cent	346	340	371	378	340
End point	408	406	419	413	390
R.v.p. at 100° F.	10.0	10.0	9.8	10.4	10.5
Sulfur	.03	.03	.15	.03	.01
Oxygen bomb ind. per hr.	10+	10+	10+	10+	10+
C.F.R.M. octane	80.0	79.9	81.2	77.4	80.0
C.F.R.M. octane plus 1 cc. TEL	...	...	...	...	88.0
C.F.R.M. octane plus 3 cc. TEL	...	...	...	...	90.0
C.F.R.R. octane	89.1	91.2	...	89.3	...
C.F.R.R. octane plus 1 cc. TEL	...	...	...	92.9	...
C.F.R.R. octane plus 3 cc. TEL	98.2	98.4	...	95.0	...

Note: These gasolines contain the C -and-heavier fractions recoverable from the wet gas.

TABLE 5—INSPECTION OF CATALYTIC GAS OILS FROM HOUDRY-PROCESSING VARIOUS STOCKS

Inspection of Houdry catalytic cracking stock:	Charge to Houdry unit— East Texas gas oil	E. Texas, Rodessa and coastal cracking stocks	California high-sulfur gas oil	East Venezuela gas oil	40% bottoms Conroe crude	Reduced Illinois crude	Mirando crude	Reduced Mid-Continent crude	Reduced E. Texas crude
Gravity, °A.P.I.	32.7	27.1	23.3	28.6	27.9	31.8	24.2	30.9	24.4
Initial	426	424	446	420	455	451	406	444	448
10 per cent	466	462	470	448	486	495	436	474	486
20 per cent	478	518	480	465	517	520	466	494	512
30 per cent	486	534	...	477	533	541	476	508	540
40 per cent	492	560	...	488	547	560	486	534	560
50 per cent	500	580	528	502	563	580	502	542	578
60 per cent	514	604	...	517	581	603	518	566	600
70 per cent	528	630	...	534	600	634	532	596	626
80 per cent	552	660	...	556	624	668	556	628	664
90 per cent	584	708	640	596	662	724	598	676	710
End point	678	752	735	704	742	760+	707	760+	760+
Recovery	98	97	98	98	98	94	98	98	94
Res.	...	...	1.0	...	...	...	0.8	1.8	3.0
An. pt., °F.	136	136	98	119	139	...	124	40	140
S.U. vis. at 100° F.	38	38	37	35	39	40	36	39	38
Con. carbon	0.03	.22	.12	.06	.05	.09	.06	...	...
Pour point, °F.	+20	+40	+5	+5	+45	+45	—36	+40	+60
Sulfur	.15	.30	.51	.48	.13	.24	.09	.12	.21

suspensoid

RESEARCH on the possibilities of the Suspensoid principle of catalytic cracking of heavy petroleum fractions was begun several years before the beginning of World War 2, by technologists of Imperial Oil, Ltd., at the refinery in Sarnia, Ont., led by Dr. R. K. Stratford, manager of research and development.

The principle used in this process is to mix the solid catalyst, which may be fuller's earth, clays, or other material, directly with the charge stock, passing the slurry through the heating coil and separating the catalyst from the heavy residuum after vaporization in the fractionator. Operating conditions are comparable approximately to mild thermal cracking.

Operation of the process has been confined to four units, converted from old Tube-and-Tank thermal operations, at Sarnia. At the beginning of the war the operation was increased in severity in order to increase the amount of butenes and other olefins formed, for use in making alkylate—butenes and synthetic rubber—butadiene. It is understood that pilot-plant facilities have been and are being installed to permit extensive research on this process as applying especially to production of motor fuels.

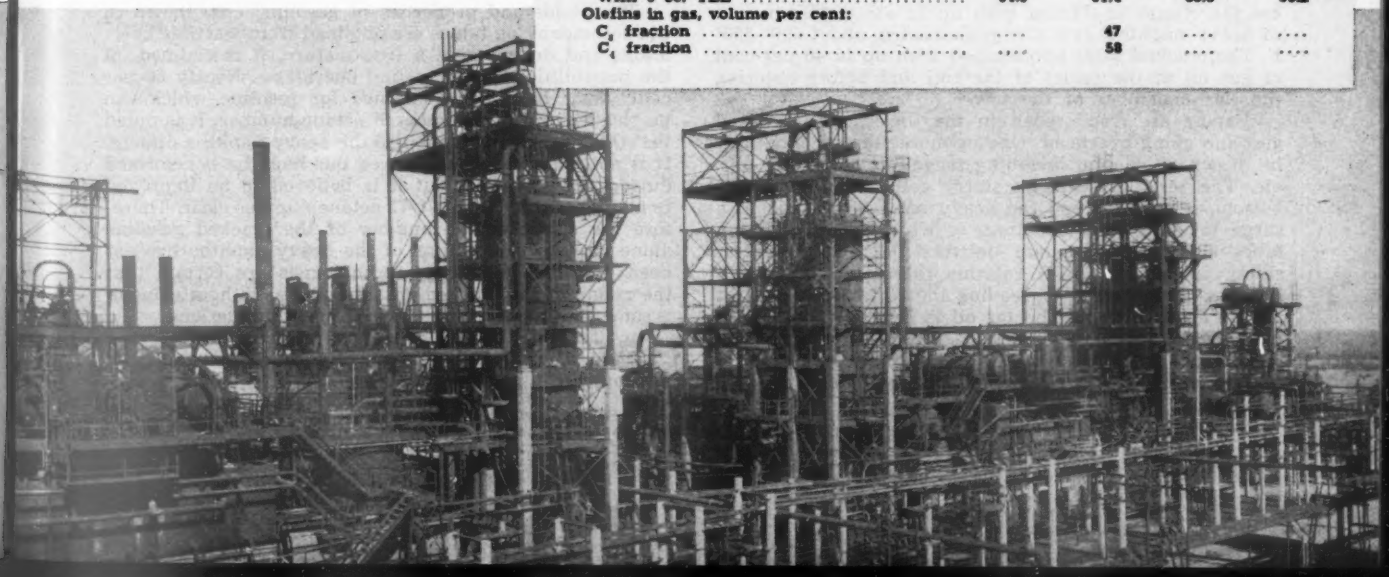
The equipment required for operating the process includes catalyst storage bins; elevating machinery such as bucket chain to hoist catalyst to an overhead bin: slurry metering and mixing equipment with a pump for handling the catalyst-charge stock slurry so mixed; pumps for charging stocks to the heater coils; furnace and coils for heating charge; fractionator tower condenser and storage equipment; filter presses for removal of catalyst from heavy residuum and conveyors and regenerating equipment for spent catalyst, along with conventional auxiliary equipment of different sorts.

The process brings charge and catalyst together by mixing them and pumping the mix through the heating coils. This method was chosen to make liquid-to-catalyst contact, rather than by holding the catalyst in fixed beds and introducing heated liquid or vapor into the reaction chambers. A portion of the charge stream is bled off and carried to a mixing unit, where measured amounts of catalyst are added continuously to form a pumpable slurry. This slurry is blended with the main charge stream and pumped through the heater coils to temperatures up to 1,050° F., when operating to make large amounts of olefin byproducts, or at lower temperatures when running principally for motor fuels, and at pressures up to 500 psig. Operations on Mid-Continent and Illinois crudes show good results when using 4-6 chrome-½-molybdenum tubes in the still.

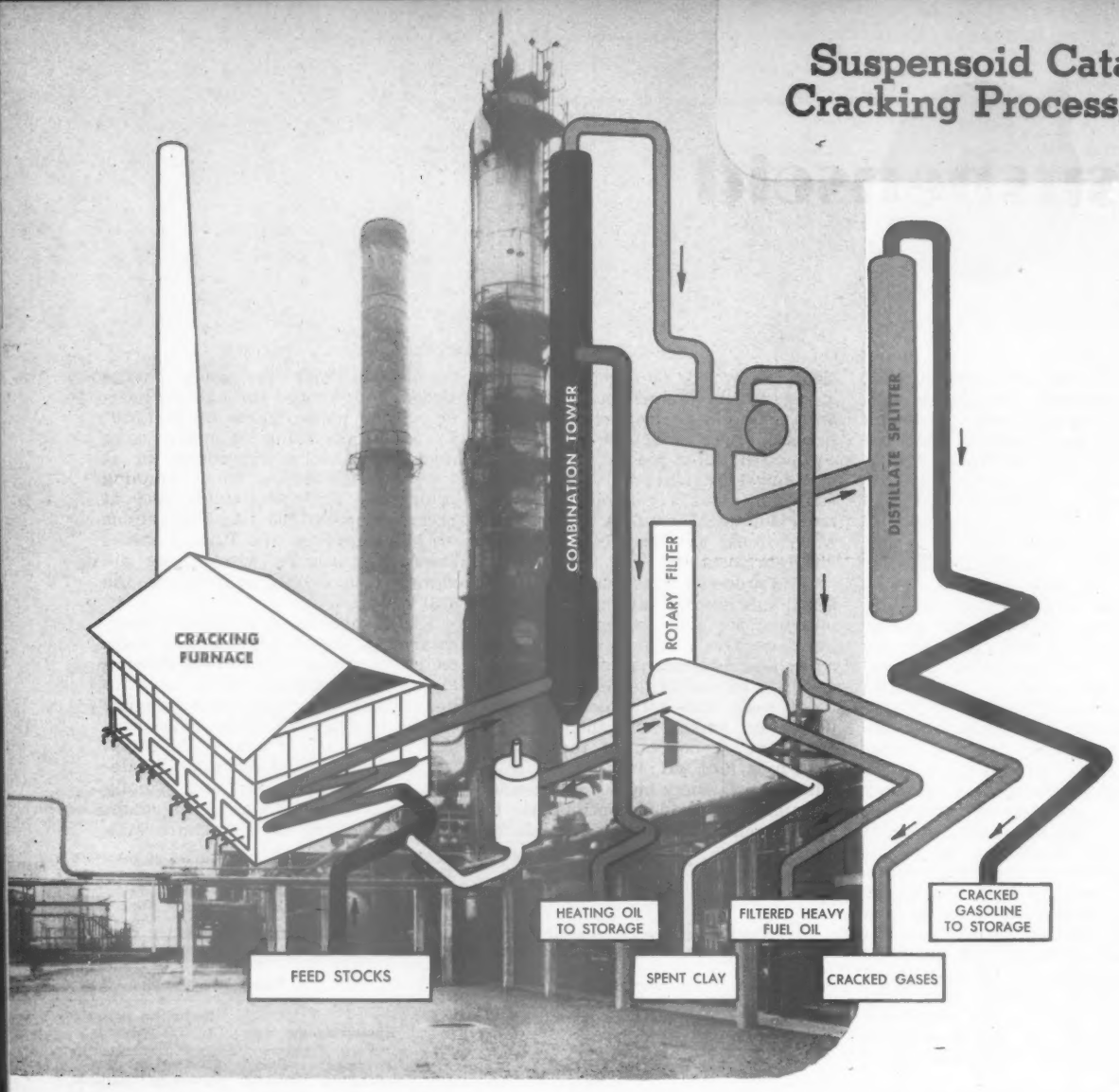
The heated mass of liquid-vapor-catalyst is discharged into the flash section of a fractionator tower through a specially designed orifice, built to maintain the necessary back pressure on the heating coil. This orifice consists of a section of pipe in the transfer line which is of continuously decreasing cross-section and finally reaches a diameter which will maintain the desired back pressure at a

TABLE 1—COMPARISON OF YIELDS AND PROPERTIES OF THERMALLY CRACKED AND SUSPENSOID CATALYTICALLY CRACKED MOTOR FUELS

	Yields, per cent			
	Excluding polymer		Including nonselective polymer	
	Thermal reforming and cracking	Suspensoid catalytic cracking	Thermal reforming and cracking	Suspensoid catalytic cracking
Gasoline, 400° F., e.p., 10-lb. R.v.p.	56.1	52.3	58.3	58.8
Excess butanes and butenes	1.3	4.5	....	....
Heating oils	12.7	12.7	12.7	12.7
Fuel oil, 10° A.P.I.	25.6	20.2	25.6	20.2
Dry gas, weight per cent	6.7	12.5	5.9	10.5
Properties of gasoline, (10-lb. R.v.p., 400° F., e.p.):				
Octane No. clear, A.S.T.M.	65.4	73.2	66.6	75.5
Octane No. clear, Research ('39)	71.0	82.0	72.6	85.1
With 1 cc. TEL	79.0	87.3	80.1	89.7
With 3 cc. TEL	84.8	91.4	85.5	93.2
Olefins in gas, volume per cent:				
C_3 fraction	....	47	....	....
C_4 fraction	....	58	....	....



Suspensoid Catalytic Cracking Process, Fig. 1



given throughput rate. This orifice is made of an extremely hard, tough alloy and by using such an alloy the erosion caused by the catalyst-charge slurry shows low values. Prior to developing this orifice back-pressure maintaining device no relief valves had been tried which would handle the problem for more than short periods. The amount of catalyst used has been about 2 lb. per barrel of charge. To reduce viscosity and to aid the process the charge is diluted with up to about 25 per cent of heavy naphtha; it is also preheated to about 500°-550° F. The cracked mass is quenched with up to 40 per cent of gas oil at the outlet of the coil and before entering the flash chamber of the tower.

Vapors are fractionated in the tower, with cracked gasoline going overhead. One or more side streams may be drawn as chosen, including recycle oils, heating oils, etc. The residuum-catalyst slurry collects in the tower bottom, is stripped and the heavy mass is pumped to a surge tower, from the bottom of which a slurry pump takes suction. This pump delivers the spent catalyst slurry directly to Oliver rotating filters through which it passes at 450°-500° F., leaving the carbonized catalyst on the drum surface. The tar oil is generally of 10°-12° A.P.I. gravity, and is used as a fuel-oil component, to make asphalt, or for any other desired purpose.

Limitation of war restrictions on equipment has prevented the operation of catalyst-recovery equipment with the cracking operation. All used catalyst has been discarded; much of the catalyst has been used previously for light filtering in making lubricating oils. Regeneration of the catalyst is comparable in requirements and any method now used for any granular, solid cracking catalyst is believed to be entirely satisfactory for use with this process.

The yields and properties of gasoline, etc., shown in the accompanying tables are obtained from wartime operations and do not give a true picture, it is claimed, of the possibilities for motor-fuel operations. Nearly 60 per cent yields have been obtained for gasoline which can be "leaded" up to 93 Research octane number. It is noted that this gasoline includes also the heavy-naphtha diluent. It is not known to what degree this naphtha is reformed during the operation, but it is believed to be improved to no higher than about 70-72 octane number clear. Therefore the actual octane number of the cracked gasoline alone without the dilution of the heavy naphtha has not been determined exactly; technologists are certain that the rating of the cracked gasoline alone, without diluent, is somewhat higher than shown in these tabulations.

Imperial Oil., Ltd., Sarnia, Ontario, is developer of this process.

thermofor

THE Thermofor catalytic cracking process receives its name from the Thermofor kiln burner which serves to regenerate the catalyst. Development both of the vapor-charge and the liquid-charge methods was carried out chiefly in the laboratories of the research and development department, Socony-Vacuum Oil Co., Inc.

The accompanying flow chart shows the main principles of the process. A large cylinder is provided as the reaction chamber. The catalyst which may be either granular or bead type enters the chamber at the top and is distributed evenly over the cylinder's cross-section, to form a solid, moving bed of catalyst. In this bed the interstices between catalyst particles are determined by

TABLE 1—TYPICAL YIELDS AND INSPECTIONS OF PRODUCTS FROM T.C.C. OPERATIONS

Type charge stock: Gas oil from mixed-base type crude
Type catalyst: Synthetic
Type process: Once-through cracking for motor-gasoline production

	Vol. % fresh charge to reactor	Gravity °A.P.I.	A.S.T.M. distillation, °F. 5%	10%	50%	90%	95%	R.v.p. (psi.)	C.F.R.M. clear octane	Saybolt color
Charge:										
Virgin gas oil	....	32.8	470	535	630	750	770	...	...	...
Tar separator bottoms	....	27.5	...	...	...	...	...	...	...	...
Reactor charge	....	33.1	490	540	632	720	737	...	...	...
Products:	100.0							9.5	78.5	30
Motor gasoline	46.0	57.3	112	127	227	375	...	...	...	...
Catalytic No. 2 fuel oil	34.0	31.6	520	524	546	582	582	...	...	...
Catalytic heavy gas oil	11.2	25.2	620	635	671	725	748	...	...	...
Excess C_4 fraction	10.3	...	...	...	...	...	...	...	...	...
Dry gas (C_3 and lighter), wt. %	4.7	...	...	...	...	...	...	...	...	...

TABLE 2—VARIATIONS IN YIELDS AND PROPERTIES FROM DIFFERENT CRUDES BY T.C.C. PROCESS

	Okla. City	California	East Texas
Charge stock:			
Crude source			
Gravity, °A.P.I.	35.7	33.6	32.7
Aniline No., °F.	189	135	166
A.S.T.M., 10%, °F.	530	438	532
50%, °F.	636	494	580
90%, °F.	730	572	660
Operating conditions:			
Average temperature, °F.	825	890	824
Pressure, psig.	10.0	10.0	10.0
Space velocity, V/V	1.8	1.4	0.8
Cat.-to-oil ratio, V/V	1.8	2.2	1.7
Recycle ratio, Bbl. recycle / Bbl. fresh feed	0	0	0
Catalyst	Bead	Bead	Bead
Yields—vol. % fresh feed:			
Gasoline	45.4	46.4	45.1
Light distillate fuel oil	28.2	38.8	43.2
Heavy gas oil	7.0	0	0
B-B, coke, gas, loss	19.4	14.8	11.7
Properties:			
Gasoline:			
R.v.p., psia.	9.7	9.5	9.5
End point, °F.	398	410	403
O.N.-M.M.	80.7	82.6	80.6
Light fuel oil:			
Gravity, °A.P.I.	32.0	29.0	28.8
Aniline No., °F.	165	113	137
Color	...	...	...
A.S.T.M., initial, °F.	425	430	450
10%, °F.	448	452	510
50%, °F.	490	481	544
90%, °F.	570	552	620
End point, °F.	635	582	686

TABLE 3—YIELDS AND PROPERTIES OF PRODUCTS MADE BY DIFFERENT T.C.C. OPERATIONS

	1	2	3	4
Charge stock:				
Crude source	Mid-Cont.	Cali-fornia	Cali-fornia	70% const. 30% paraf.
Gravity, °A.P.I.	33.9	32.6	32.9	27.3
Aniline No., °F.	157	123	138	147
A.S.T.M., 10%, °F.	490	423	423	488
50%, °F.	594	498	497	582
90%, °F.	721	585	614	†700
Operating conditions:				
Average temperature, °F.	875	893	844	905
Pressure, psig.	6.5	8.2	8.5	6.5
Space velocity, V/V	2.12	0.72	1.7	1.71
Cat.-to-oil ratio, V/V	1.6	2.0	1.7	1.81
Recycle ratio, Bbl. recycle / Bbl. fresh feed	0.38/1.6	0	0.33/1.6	0
Catalyst	Clay	Clay	Clay	Clay
Yields—vol. % fresh feed:				
Gasoline	37.0	41.6	55.7	36.9
Light distillate fuel oil	41.6	49.1	30.9	42.6
Heavy gas oil	13.8	5.4	3.1	8.9
B-B, coke, gas, loss	7.6	3.7	11.3	12.6
Properties:				
Gasoline:				
R.v.p., psia.	6.0	5.9	2.8	4.9
End point, °F.	410	401	440	420
O.N.-M.M.	76.7	76.9	70.8	76.7
Light fuel oil:*				
Gravity, °A.P.I.	33.4	31.6	30.0	28.5
Aniline No., °F.	140	117	126	...
Color	1	2	1	1½
A.S.T.M., initial, °F.	454	395	427	420
10%, °F.	494	442	477	470
50%, °F.	512	470	508	520
90%, °F.	584	532	585	590
End point, °F.	600	581	597	625
Heavy gas oil:				
Gravity, °A.P.I.	26.2	17.6	14.2	19.0
A.S.T.M., initial, °F.	500	470	481	490
10%, °F.	516	546	571	582
90%, °F.	648	591	625	698

*Cetane No. 43.6 S.U.V. at 100° F., 35 sec. †94 per cent.

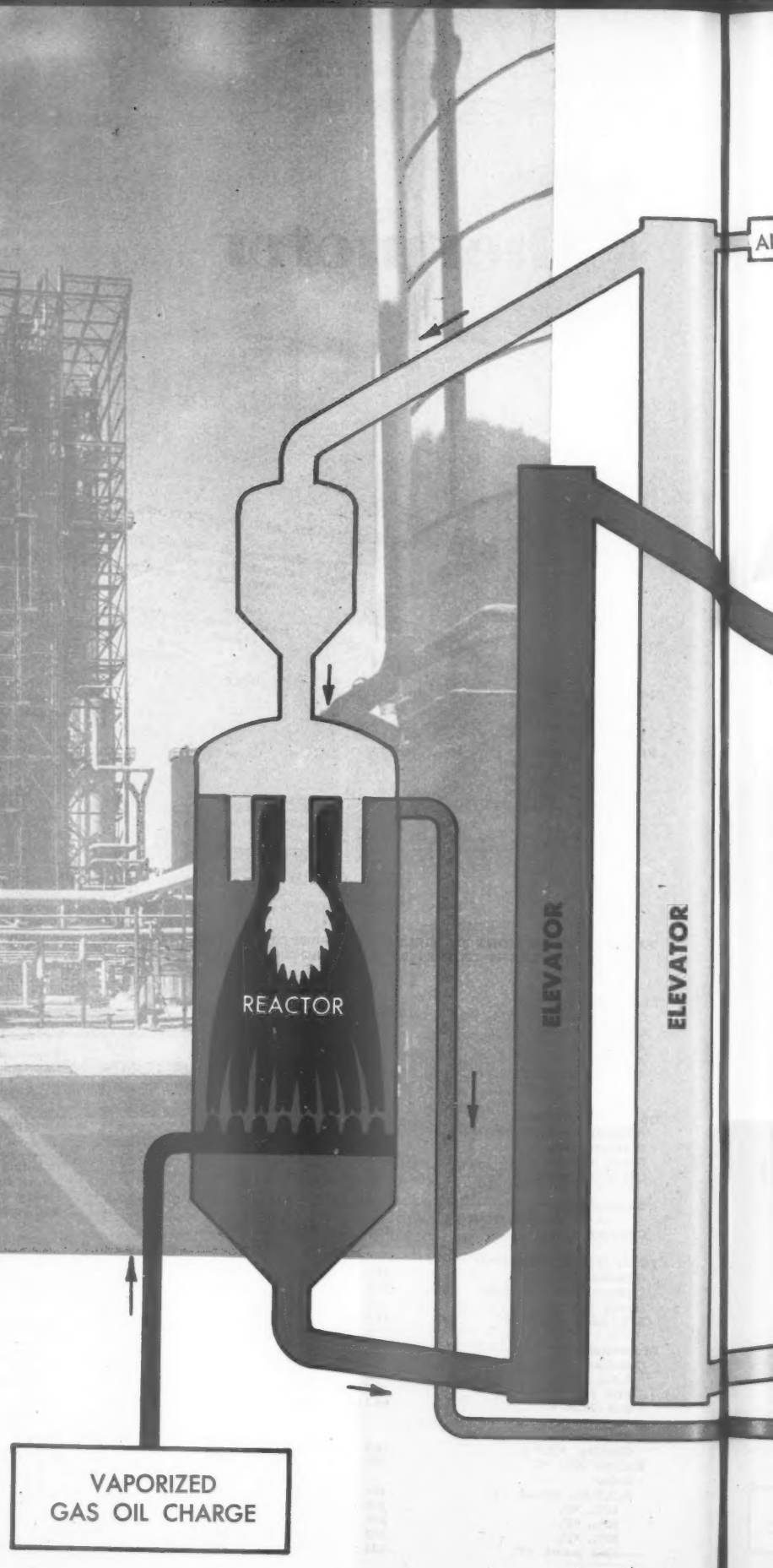
shape and size of the particles, and it is through these interstices that the liquid or vapor charge passes, thus being brought into intimate contact with the catalyst. This moving bed passes slowly downward through the reactor, and spent catalyst is removed from the bottom of the reactor.

The kiln is designed to provide the maximum burning capacity which may be required by the maximum throughput of the unit. Since carbon cannot be deposited more rapidly than it can be burned by the kiln capacity, it results that the kiln may be the "bottleneck" of the unit. A unit charging 10,000 bbl. per day of gas oil may deposit up to 10,000 lb. of carbonaceous matter per hour. Under such operations the unit may circulate catalyst at the rate of 200 tons per hour with the heavy charge, or down to half that much with light charge stocks.

Other and auxiliary equipment includes two elevators, or a double elevator to lift spent catalyst from the reactor drawoff to the top of the kiln, and similarly to raise regenerated catalyst again to the hopper above the reactor from which it is fed into the reactor top. Blowers are provided to drive a mixture of air and flue gas through the kiln countercurrent to the direction of passage of the catalyst being regenerated. Hot flue gases from this burning may be used to produce large quantities of steam required by the refinery by passing the tail gas from the kiln through the heating section of waste heat boilers.

In the liquid phase technique, total liquid, total vapor or a mixture of vapor and liquid may be charged to the reactor, or each may be introduced separately, alternating the vapor and liquid charge. The charge in either form may be introduced into the reactor, after preheating, at 825° to 900° F. Catalyst from the regenerator kiln may be brought in at 1,000° to 1,100° F. In this manner the average reactor temperature may range from 850° to 925° F. as typical extremes. Volumetric catalyst-to-oil ratios may vary from 0.5 or even less to 6. Pressure in the reactor is nominal.

Vapors or liquid are withdrawn from the reactor and fractionated to yield two or three streams, normally; overhead gasoline fraction, a light gas or furnace oil from the tower side and a heavy gas oil from the bottom. Octane rating of the gasoline fraction may be 76 to 82 A.S.T.M. as a typical range, or 85 to 93 C.F.R.-Research or C_2 methods. The light gas oil may show a cetane number of 40-45 from paraffin-base stocks, or lower from naphthenic stocks.



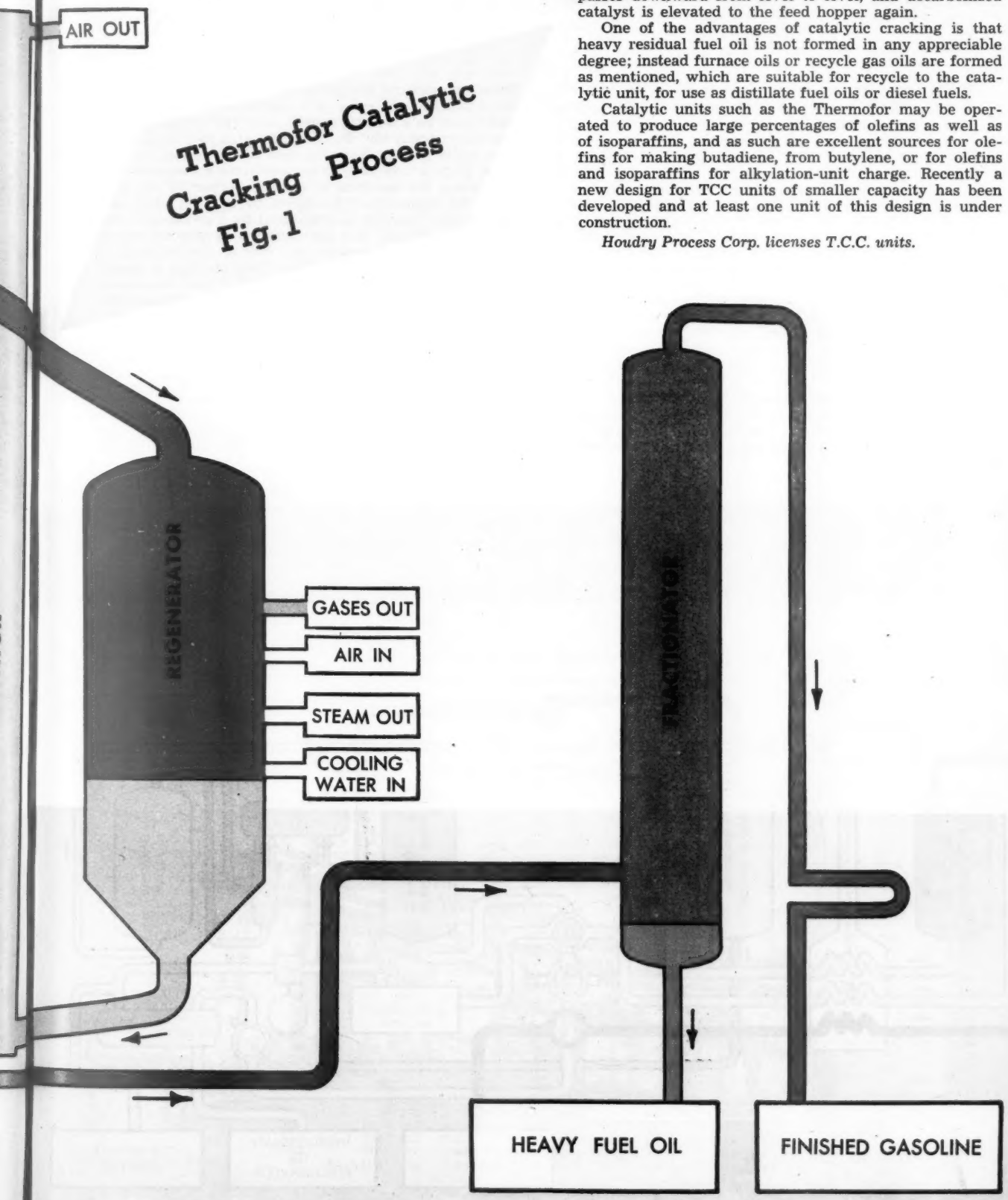
Spent catalyst is drawn continuously from the bottom of the reactor, a jet of steam or flue gas driving traces of hydrocarbon out of the mass. By a bucket conveyor system the catalyst is elevated to the top of the kiln, passes downward from level to level, and decarbonized catalyst is elevated to the feed hopper again.

One of the advantages of catalytic cracking is that heavy residual fuel oil is not formed in any appreciable degree; instead furnace oils or recycle gas oils are formed as mentioned, which are suitable for recycle to the catalytic unit, for use as distillate fuel oils or diesel fuels.

Catalytic units such as the Thermofor may be operated to produce large percentages of olefins as well as of isoparaffins, and as such are excellent sources for olefins for making butadiene, from butylene, or for olefins and isoparaffins for alkylation-unit charge. Recently a new design for TCC units of smaller capacity has been developed and at least one unit of this design is under construction.

Houdry Process Corp. licenses T.C.C. units.

Thermofor Catalytic Cracking Process
Fig. 1



hydroforming

THE hydroforming process is essentially the catalytic reforming of heavy, low-grade naphthas from topping or cracking operations in the presence of hydrogen gas. It was developed by the Kellogg Co., Standard Oil Co. (Indiana) and Standard Oil Development Co. Instead of hydrogenating olefins, etc., in the charge, the process actually robs the charge of some hydrogen, producing mainly aromatics. Charging naphtha of up to 50 octane number A.S.T.M., the process yields 80 per cent or more of hydroform polymer of 80-90 A.S.T.M. octane number, clear, with a blending octane rating of more than 100.

The product is highly aromatic; one naphtha, showing a yield of 80 per cent of 80 A.S.T.M. octane number gasoline, contains 40 to 50 per cent of aromatics. This aromatic fraction contains 15 to 20 per cent of toluene, or 7.5 to 10 per cent of the total yield. The remainder of the aromatics present are xylenes, that is, dimethyl benzenes, ethyl, propyl and i-propyl benzene (cumene) and higher aromatics.

The process operates essentially as follows:

Naphtha is charged to a heater where it is raised to a temperature of 950° F. or higher while in another coil a recycle gas rich in hydrogen is heated to 1,000°-1,050° F. These two streams are mixed and sent to the reactor at about 250 psig. to come into contact with the catalyst, which may be a natural metal oxide. The reaction is carried out at about 950° F., being reheated in a second furnace while passing from the first to the second reactor.

In units where two series reactors are employed for completing the reaction, at least four reactors are provided. To regenerate the catalyst by burning away carbon deposit, fresh air is introduced by a compressor and mixed with recycle flue gas until the oxygen content of the mixture is satisfactory, say, four or five volumes of flue gas per volume of fresh air. This mixture is heated in a special heater to about 600°-700° F. and introduced into the reactor, the catalyst in which is to be regenerated; pressure is maintained at about 250 psig. and the combustion gases exit at around 1,100° F. A portion of this hot gas passes through the furnace of a waste heat boiler and is recycled, all or part.

At the completion of a regeneration cycle the major part of the catalyst has a temperature of 600°-700° F. The amount of air-flue gas mixture and its oxygen content are so regulated that the catalyst during regeneration does not reach a temperature higher than 1,050°-1,100° F.;

Hydroforming Reaction and Regeneration Section
Fig. 1

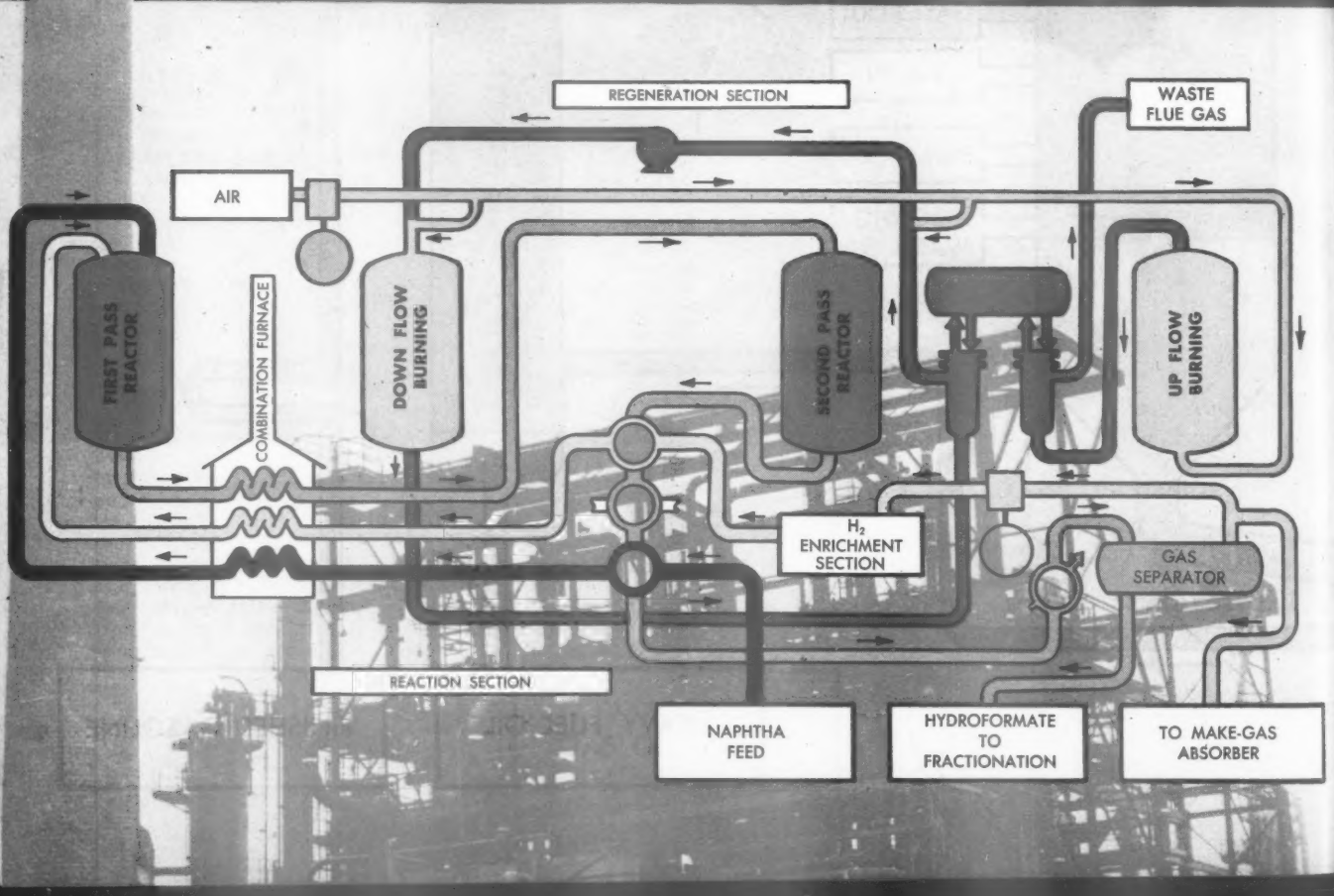


TABLE 1

CHARGE STOCKS, CATALYSTS AND OPERATING CONDITIONS IN HYDROFORMING PROCESSING

Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Source of feed:	Mixtures W. Tex. and Mid-Cont. virgin naphthas*								Mid-Continent Virgin naphthas										
Kind of catalyst:	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Low soda		
Age of catalyst in stream days	148	155	162	169	187	194	201	208	79	85	89	90	98	....	....	....	117	126	150
Naphtha coil outlet, °F.	950	946	940	940	940	935	930	930	950	913	924	924	989	940	970	970	970	985	1,000
Recycle gas coil outlet, °F.	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,030	1,040	1,040
Reheat transfer line, °F.	944	941	941	940	944	939	934	935	975	940	940	940	1,000	943	959	957	....	....	....
Catalyst bed temp.:																			
Primary reactor, °F.	914	905	896	899	893	900	908	911	913	880	978	880	938	905	922	922	910	916	940
Secondary reactor, °F.	912	906	905	906	914	910	905	904	934	896	895	894	963	911	925	924	899	915	938
Drop through catalyst bed:																			
Primary reactor, °F.	86	96	100	99	105	94	87	81					....	131	130	132	111	109	89
Secondary reactor, °F.	34	34	36	34	36	36	38	34						68	63	55	50	49	41
Reaction pressure, psig.	216	222	222	222	230	222	224	226	230	222	225	225	225	236	238	236	214	217	215
Space velocity, Vo/Hr/Vc	0.42	0.42	0.43	0.42	0.44	0.44	0.46	0.45	0.86	0.68	0.83	0.82	0.85	0.53	0.50	0.49	0.44	0.44	0.46
Reaction period, hours	4½	4½	4½	4½	4½	4½	4½	4½	6	6	6	6	6	6½	6½	7½	6¼	6½	7
Recycle gas, SCF/bbl. charge	3,240	3,500	3,600	3,600	3,500	3,450	3,350	3,400	2,980	2,520	1,805	1,830	2,950	2,500	2,840	2,650	2,940	2,890	2,780
Volume % hydrogen in recycle	72	73	73	73	73	73	73	73	65.0	73.7	76.0	73.8	53.6	73	76	76	74	73	77
Naphtha charge:																			
Gravity, °A.P.I.	49.7	49.3	49.9	50.5	51.0	50.9	51.4	51.2	52.6	53.0	53.4	54.3	54.1	53.7	51.5	52.5	52.0	51.9	51.3
A.S.T.M. distillation, °F.:																			
I.b.p.	156	183	180	174	157	166	158	153	218	225	220	212	218	206	212	208	230	238	224
10%	241	253	250	236	229	231	216	214	260	258	256	250	253	244	253	250	264	264	246
50%	320	330	320	311	310	307	294	292	310	310	304	298	296	302	329	319	306	307	302
90%	402	410	396	384	385	384	372	375	370	370	364	358	355	369	378	377	384	387	394
End point	469	468	455	442	434	430	421	427	420	412	406	406	402	406	408	412	447	460	462
Octane number, C.F.R.-M	39.3	37.4	37.8	39.7	41.5	42.4	45.7	45.3	33.5	34.0	34.0	34.9	34.3	35.4	34.4	34.4	36.4	36.1	35.8
Aniline point, °F.	123	126	129	124	124	119	114	113	..	..	..	....	....	118	171	140	134	132	134
Bromine number	3.2	2.7	2.2	2.2	2.0	1.8	2.2	2.3	.	....	....	....	....	....	0.8	1.0	0.4	1.1	0.9
Lamp sulfur, weight %	0.309	0.251	0.202	0.220	0.195	0.276	0.310	0.338	..	....	....	....	....	0.021	0.023	0.031	0.027	0.020	0.029

*Approximately two-thirds West Texas and one-third Mid-Continent virgin naphtha.

TABLE 2

YIELDS, WEIGHT BALANCES, AND PROPERTIES OF HYDROFORMATE

Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Source of feed:	Mixtures W. Tex. and Mid-Cont. virgin naphthas								Mid-Continent Virgin naphthas										
Kind of catalyst:	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Low soda		
Yields, Vol. % of feed (output):																			
C_5-free gasoline	71.1	72.5	73.5	73.6	71.8	74.2	75.8	75.1	76.5	85.6	86.6	86.1	71.4	76.9	74.9	76.3	*82.8	*78.5	*75.8
Butanes	12.0	10.5	9.9	10.6	12.0	12.0	12.3	11.9	6.0	3.7	3.4	3.6	6.1	5.6	5.0	5.4	3.5	5.4	6.2
Polymer	3.0	3.4	3.4	3.2	3.5	3.0	2.1	2.3	2.6	2.2	1.7	1.7	1.7	2.0	3.3	2.5	*3.7	*3.8	*3.6
Yields, Wt. % of feed (output):																			
C_5-free gasoline	73.3	74.6	75.8	76.0	74.2	76.5	78.9	77.5	79.3	87.4	88.6	88.4	74.4	79.2	76.4	78.1	83.8	81.0	77.1
Butanes	8.8	7.7	7.3	7.8	8.8	8.8	9.1	8.8	4.4	2.8	2.6	2.6	4.8	4.3	3.7	4.1	2.6	4.0	4.6
Polymer	3.9	4.3	4.3	3.9	4.5	3.8	2.6	3.1	3.3	2.8	2.2	2.1	2.2	2.6	4.1	3.2	4.6	4.8	4.6
C_5-free gas	12.1	11.6	11.0	10.7	10.8	9.3	7.8	9.1	11.5	6.0	5.8	6.1	16.8	12.9	14.6	13.4	8.4	9.3	12.7
Carbon	1.9	1.8	1.8	1.6	1.7	1.6	1.6	1.5	1.5	1.0	0.8	0.8	2.0	1.0	1.2	1.2	0.8	0.9	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Over-all wt. balance (% feed)	99.2	99.0	98.9	99.2	98.5	97.5	95.6	98.2	101.8	100.2	98.9	98.8	103.1	99.6	101.6	101.2	100.0	101.0	99.1
Net, C_5-free gas, SCF/bbl. chg.	732	851	790	748	705	621	549	540	1,056	751	712	709	1,241	1,095	911	895	....	....	....
Net, hydrogen, SCF/bbl. chg.	274	....	358	374	312	289	253	199	670	556	528	503	680	....	....	....	....	....	....
Gasoline as produced:																			
Gravity, °A.P.I.	50.4	49.8	50.4	50.5	51.4	51.2	51.5	51.6	49.6	51.4	51.7	51.6	49.4	51.7	50.0	50.1	52.1	51.2	50.3
A.S.T.M. distillation, °F.:																			
I.b.p.	100	107	102	104	104	102	112	109	106	115	120	110	106	119	111	127	120	106	104
10%	149	159	153	156	148	152	156	152	176	196	198	198	170	174	165	175	202	182	184
50%	258	267	268	256	253	257	249	248	278	285	278	278	268	265	269	265	283	270	250
90%	352	359	345	338	340	341	335	335	348	356	352	350	338	343	348	348	346	343	367
End point	407	411	406	399	393	398	396	397	406	403	402	426	396	386	393	398	390	416	404
Octane No., C.F.R.-M clear	79.7	80.2	79.8	80.3	80.6	80.2	79.6	79.4	74.5	68.8	66.0	67.8	78.5	74.1	76.6	76.2	69.2	71.4	74.6
+1 cc. TEL	....	....	....	....	....	....	....	....	82.0	77.0	76.0	77.0	84.3	....	....	....	78.4	78.9	82.3
+3 cc. TEL	....	....	....	....	....	....	....	....	86.7	83.1	82.0	83.0	88.0	85.8	86.1	86.1	83.3	84.1	84.5
Reid vapor pressure	9.4	8.8	8.8	8.9	10.1	10.1	10.2	10.3	4.6	5.4	3.5	3.5	5.2	4.5	5.1	4.9	6.9	6.6	5.9
Aniline point, °F.	49	51	54	57	52	49	53	53	..	..	....	....	....	95	64	87	87	83	76
Bromine number	3.4	3.3	3.1	3.2	3.2	3.0	2.7	2.7	....	....	....	....	....	3.1	4.0	4.0	2.1	2.0	1.3
Lamp sulfur, weight %	0.021	0.016	0.014	0.015	0.022	0.028	0.017	0.015	..	....	....	.. ..	....	0.001	0.008	....	0.008	0.009	0.005
C_5-free gas analysis (Vol. %):																			
H_2	37.4	...	45.3	50.0	44.2	46.5	46.1	38.8	62.5	74.1	74.2	71.0	53.1	....	....	....	....	....	....
CH_4	31.1	....	31.2	21.5	26.7	24.6	28.1	30.8	16.6	13.5	13.0	16.1	21.6	....	....	....	....	....	....
C_2H_6	17.6	....	13.1	15.4	16.2	15.1	14.9	19.6	11.0	6.8	6.8	6.9	14.2	....	....	....	....	....	....
C_3H_8	13.9	....	10.4	13.1	12.8	13.8	10.9	12.8	8.9	5.6	6.0	6.0	11.1	....	....	....	....	....	....
Total	100.0	..	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	....	....	....	....	....	....
Polymer gravity, °A.P.I.	9.7	10.2	11.0	11.1	11.8	11.5	11.3	11.6	12.6	14.3	15.5	15.2	8.8	12.5	11.8	11.4	17.1	13.9	10.7

*Corrected value used in product distribution charts. See explanation in discussion.

TABLE 3

YIELDS OF HYDROFORMED GASOLINES, VAPOR PRESSURES, OCTANE RATINGS, ETC.

Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Source of feed:	Mixtures W. Tex. and Mid-Cont. virgin naphthas								Mid-Continent Virgin naphthas								Low sods		
Kind of catalyst:	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel			
C_5-free gasoline:																			
Yield (Vol. % feed, output)	71.1	72.5	73.5	73.8	71.8	74.2	75.8	75.1	76.5	85.6	86.6	86.1	71.4	76.9	74.9	76.3	†82.8	†79.5	†75.8
Reid vapor pressure	*2.0	*2.0	*2.0	*2.0	*2.0	*2.0	*2.0	*2.0	1.4	2.9	1.1	1.5	2.6	3.1	3.5	3.4	*2.0	*2.0	*2.0
Octane No., C.F.R.-M clear	77.7	78.5	78.0	78.5	78.4	78.0	77.4	77.1	73.5	67.7	65.0	67.0	77.8	73.7	76.2	75.8	68.3	70.0	73.7
+1 cc. TEL	...	....	83.8	....	....	....	....	83.5	80.9	75.8	74.9	76.2	83.6	....	....	....	77.4	77.4	81.3
+3 cc. TEL	....	....	86.8	....	....	....	....	87.7	85.6	81.9	80.9	82.2	87.3	85.4	85.7	85.8	82.3	82.6	86.3
100% C_5-free recovery gasoline:																			
Yield (Vol. % feed, output)	83.1	83.0	83.4	84.2	83.8	86.2	86.1	87.0	82.5	89.3	90.0	89.7	77.5	82.5	79.9	81.7	†86.3	†84.9	†82.0
Reid vapor pressure	11.1	10.3	9.5	9.9	10.9	10.8	10.7	10.5	6.3	5.8	3.8	4.3	7.6	7.5	7.4	7.6	4.9	6.3	7.0
Octane No., C.F.R.-M clear	80.1	80.8	80.0	80.6	80.8	80.4	79.8	79.5	75.0	68.8	66.1	68.2	79.1	75.2	77.4	77.1	69.4	71.6	75.4
+1 cc. TEL	....	....	86.0	....	....	....	....	86.2	82.6	77.0	76.1	77.5	85.0	....	....	....	78.6	79.1	83.2
+3 cc. TEL	....	....	89.0	....	....	....	....	90.3	87.3	83.1	82.1	83.5	88.7	87.0	87.0	87.1	83.5	84.3	88.4
10 lb. R.v.p. gasoline:																			
Yield (Vol. % feed, output)	81.4	82.7	84.0	84.4	82.3	84.8	86.3	86.2	80.1	85.7	89.6	90.7	80.2	86.2	83.7	85.3	†83.8	†80.4	†86.5
Octane No., C.F.R.-M clear	79.8	80.5	80.1	80.7	80.5	80.1	79.6	79.3	76.3	70.5	68.8	70.6	79.7	76.0	78.2	77.9	71.5	73.0	76.4
+1 cc. TEL	....	....	86.1	....	....	....	....	86.0	84.1	78.9	78.1	80.1	85.7	....	....	....	80.8	80.7	84.3
+3 cc. TEL	....	....	89.1	....	....	....	....	90.1	88.8	85.0	85.1	86.1	89.4	87.9	87.9	88.0	85.7	85.9	88.5
Excess or deficiency of butane above 10-lb. R.v.p. gasoline (Vol. % feed, output)	+1.7	+0.3	—0.6	—0.2	+1.5	+1.4	+1.2	+0.8	—5.6	—6.4	—9.6	—9.0	—2.7	—3.7	—3.8	—3.6	—7.5	—5.5	—6.8

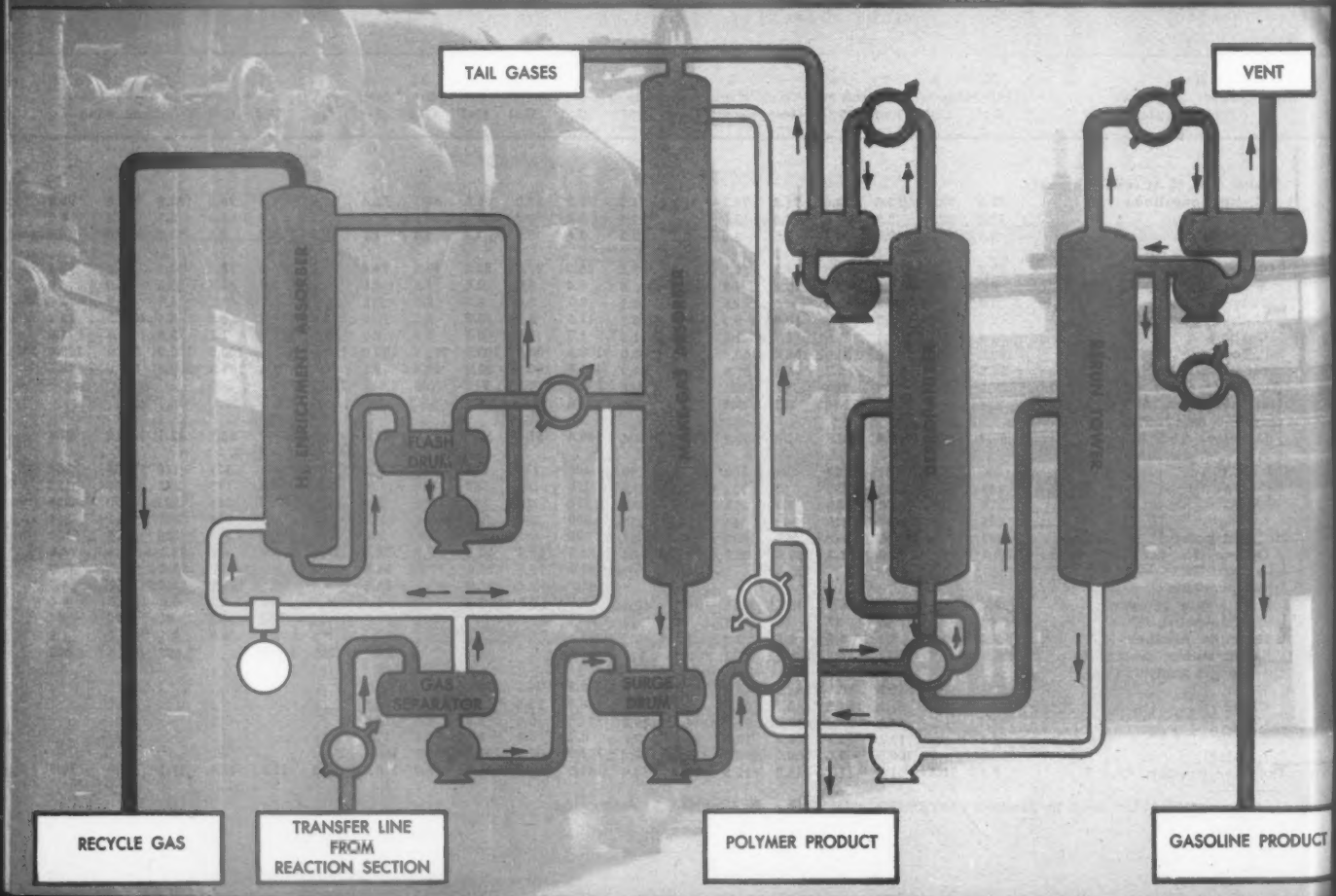
*Assumed. †Corrected value used in product distribution charts. See explanation.

otherwise the catalyst activity is reduced. Operating, yield and property details are shown in Tables 1, 2, and 3.

Distillate from a hydroforming unit is an excellent source of aromatics, especially toluene, the xylenes, etc. During World War 2, immense quantities of toluene of nitration grade were segregated in several American refineries, from hydroformer distillate. By no means all of the hydroformer distillate lies in the motor boiling range. Above the motor-fuel range, or about 400°-425° F., is a small (2-4 per cent) fraction called "hydroformer polymer" which is formed partially at least by polymerization. This fraction is reported to show A.P.I. gravity of 11.0° to 15.0°, ranging from 230 to 265 specific refractivity. These properties indicate the highly polycyclic nature of the molecules making up the material.

M. W. Kellogg Co. and Universal Oil Products Co. license this process.

Hydroformer Recovery Section, Fig. 2



hf alkylation

ALKYLATION of isoparaffins and olefins with anhydrous hydrofluoric acid as catalyst is the newest of the alkylation processes which have progressed well into the commercial stage. The reaction is essentially identical with that taking place when sulfuric acid is the catalyst; olefins combine with isoparaffins to form heavier hydrocarbons, the molecular weight of which is the sum of the molecular weights of the reactants. This process differs from that using sulfuric acid in that the acid catalyst may be recovered and can be reused indefinitely as the catalyst for this reaction.

HF alkylation was discovered before the outbreak of World War 2 but had not progressed to the commercial stage. A large number of units were built during the war and design was not improved as rapidly as would have occurred in peacetime due to the necessity for increasing alkylate capacity and production at any cost for war purposes. More recently numerous improvements have been made in the design which are mentioned later herein.

The process consists essentially of mixing anhydrous HF with isobutane which has been dried with bauxite or other desiccant, and pumping this mix along with an olefin into the reaction chamber. Reaction temperatures range from about 75° F. to about 115° F., although these values are not entirely limiting. The hydrocarbon-catalyst ratio is maintained at approximately 1:1. Isoparaffin to olefin ratio may vary widely, 7:1 to 12.5:1 for examples. This condition is maintained, of course, to prevent or minimize polymerization of olefin, and thus to promote the alkylation reaction. Pressures are nominal and used mainly to hold reactants in the liquid form, ranging up to 100-150 psig. Normally in temperate zone climates it is not necessary to use artificial refrigeration to obtain satisfactory yields in this process.

In almost if not all cases the reactants are mixed violently by the use of a powered-mixer such as the Stratford units installed in existing plants. After settling out to separate most of the catalyst from the product, the catalyst is withdrawn from the settler bottom and recycled to the mixer. The reaction liquid passes to the prefractionator or HF stripper tower where all but traces

TABLE 1—TYPICAL OPERATION OF HF ALKYLATION UNIT

	Bbl. per day
Charge to unit:	
Propylene	89
Butylene	869
Amylenes	246
Total olefins	1,224
Saturated hydrocarbons*	1,862
Total feed	3,086
Recycle isobutane, bbl. per calendar day†	10,300
Yields:	**Bbl. per day**
Aviation alkylate	2,070
Heavy alkylate	134
Isopentane	190
Normal pentane	349
Propane	166
Acid-soluble oils	20
Aviation alkylate yield, bbl. per bbl. olefin	1.7
Isobutane consumption, bbl. per bbl. olefin	1.2
Operating conditions:	
Isobutane: Olefin ratio	7.05
Acid: Hydrocarbon ratio	1.0
Pressure, psi.	150
Temperature, °F.	102
Contact time, minutes	15
Acid catalyst:	
Titrable acidity, wt. %	89.6
Oils plus solids, wt. %	3.0
Water, wt. %	1.6

*Contains 418 bbl. isobutane. †Total stream—80% purity.

TABLE 2—TYPICAL PRODUCTS OF HF ALKYLATION

	Depentanized aviation alkylate	Heavy alkylate
Gravity, °A.P.I.	83.8	45.3
A.S.T.M. distillation, °F.:		
I.b.p.	184	416
10%	208	428
50%	225	443
90%	254	538
End point	370	616
Reid vapor pressure, lb.	1.1	....
Octane number, A.S.T.M.	90	75

TABLE 3—UTILITY AND CHEMICAL CONSUMPTION HF ALKYLATION

Basis—3,000 bbl. per day aviation alkylate—war operation
3,400 bbl. per day motor alkylate—redesigned peacetime plant

	Wartime operation	New design
Utilities:		
Steam, lb. per hr.	115,000	90,000
Electricity, kw.	1,300	950
Water circulation, g.p.m.	5,300	4,600
Water makeup, g.p.m.	283	247
Fuel gas, cu. ft. per hr.	12,100	1,200
Chemicals, lb. per month:		
Caustic soda	9,850	9,850
Bauxite	105,000	32,000
Hydrofluoric acid	90,000	27,000
Lime	1,500	1,500
Labor:		
Operation, man-hours per day	157	157
Maintenance, man-hours per day	105	105

of catalyst are removed and returned to the catalyst container. Bottoms from this tower are used to preheat incoming reaction mixture to the same tower, and then passes to treaters where solid bauxite removes the last HF which is normally combined with organic groups. The bauxite is used for this purpose until its reactivity falls below some predetermined level and is then mixed with lime, etc., and discarded. Temperatures used for this defluorination are normally 180°-185° F. though this temperature is not critical.

After fractionation to remove unreacted butanes, or other light hydrocarbons the product is again bauxite-treated to remove the last traces of fluorine. The raw, untreated alkylate normally contains 0.01 to 0.025 per cent of fluorine in a combined state when charged to the first bauxite tower. The effluent from this tower has been reduced to 0.001 per cent fluorine, while the finished product from the debutanizer after having a second bauxite treatment contains only traces of fluorine.

The recovered HF is purified continuously by distillation. A portion of the fouled acid is bled off the return line to a column in which dissolved hydrocarbons and some HF are distilled over and returned to the settling drum. Bottoms from this tower are reheated and flashed in a tower and with careful reboiling of the bottoms product. Bottoms are discarded after reboiling. Purified HF is taken overhead in this tower and returned to catalyst acid storage for reuse in the system. Many of these units are tied in with isomerization units.

A theory has been developed to explain this alkylation reaction, called the carbonium theory. It is assumed that the isoparaffin is ionized in some degree, forming an H+ ion and a negative carbonium ion which is the remainder of the isoparaffin molecule. This carbonium ion then is believed to combine with the olefin forming a larger carbonium ion, also lacking one hydrogen. This new ion combines with the H+ ion to complete the alkylation reaction.

Alkylation of an isoparaffin, such as isobutane, with olefins, such as propylene, butylenes or amylenes, using hydrofluoric acid as a catalyst has now become a well established process for producing high octane-number aviation or motor fuels. The typical flow diagram for the process has been described previously.

The oldest commercial HF alkylation unit has been operating somewhat more than 3 years. As would be expected with a process of such recent development, many improvements have been worked out since end of the war as a result of increasing operating experience. However, the urgency of maximum production during the war and the uncertainty of the economic picture during reconversion has delayed commercial installation of all but the most urgent modifications. It is now possible to design new units or to simplify old ones, in such a manner to obtain both lower installation and operating costs.

New Economic Design

The major changes which would be considered by a designer in planning a new unit or in revamping an old one include the following:

1. Installation of the defluorinating step downstream from the deisobutanizer. This step eliminates defluorination of the recycle isobutane with resultant savings in hydrofluoric acid and other chemical consumption.

2. Combination of the main azeotropic fractionation step with the deisobutanizing step, one fractionator serving both functions. A small azeo tower could be used on a bleed stream to a depropanization step. This change would result in savings in capital investment, utilities, and in maintenance.

3. Simplification of the acid-rerun equipment by use of a single column, acid-soluble oil and water being removed at the bottom of this column together, and by the use of a higher column pressure to eliminate the necessity of overhead product pumps with attendant savings in maintenance.

4. In production of alkylate for motor-fuel blending, the fractionation of aviation alkylate from heavy alkylate could be eliminated in most cases with further savings in utilities, and in capital investment for a new plant.

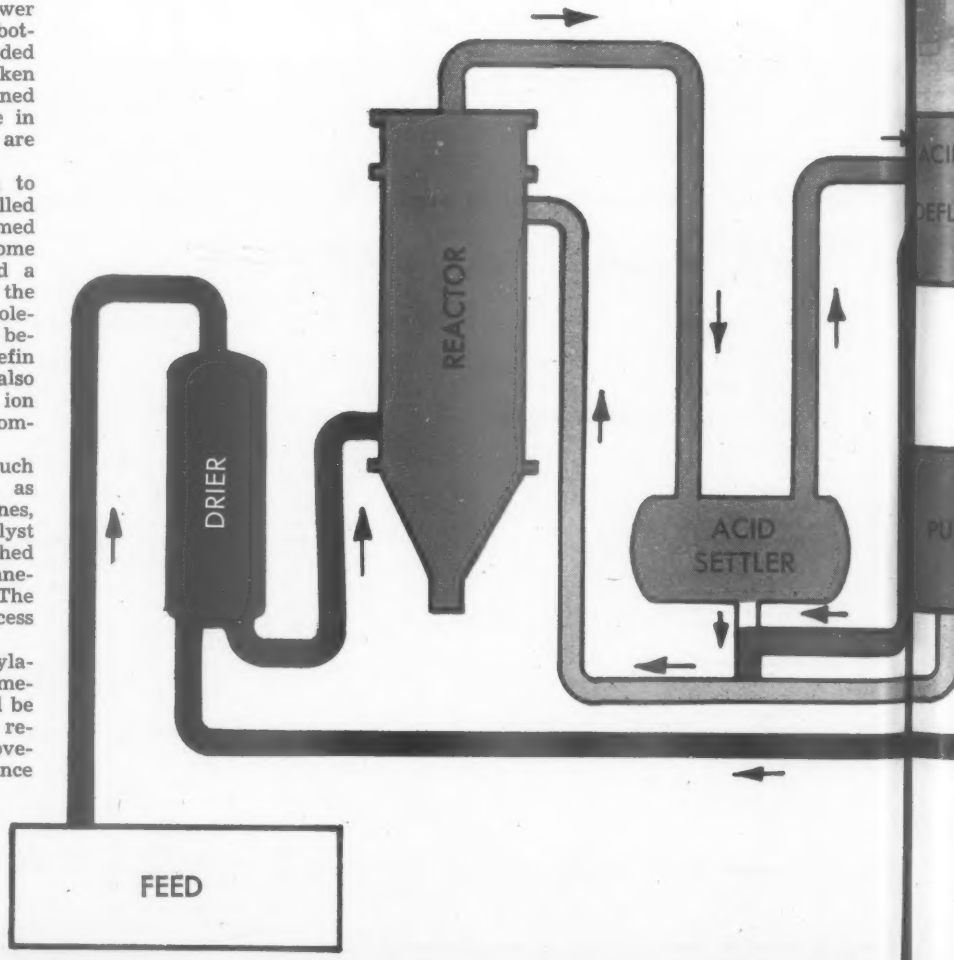
Typical Operating Data

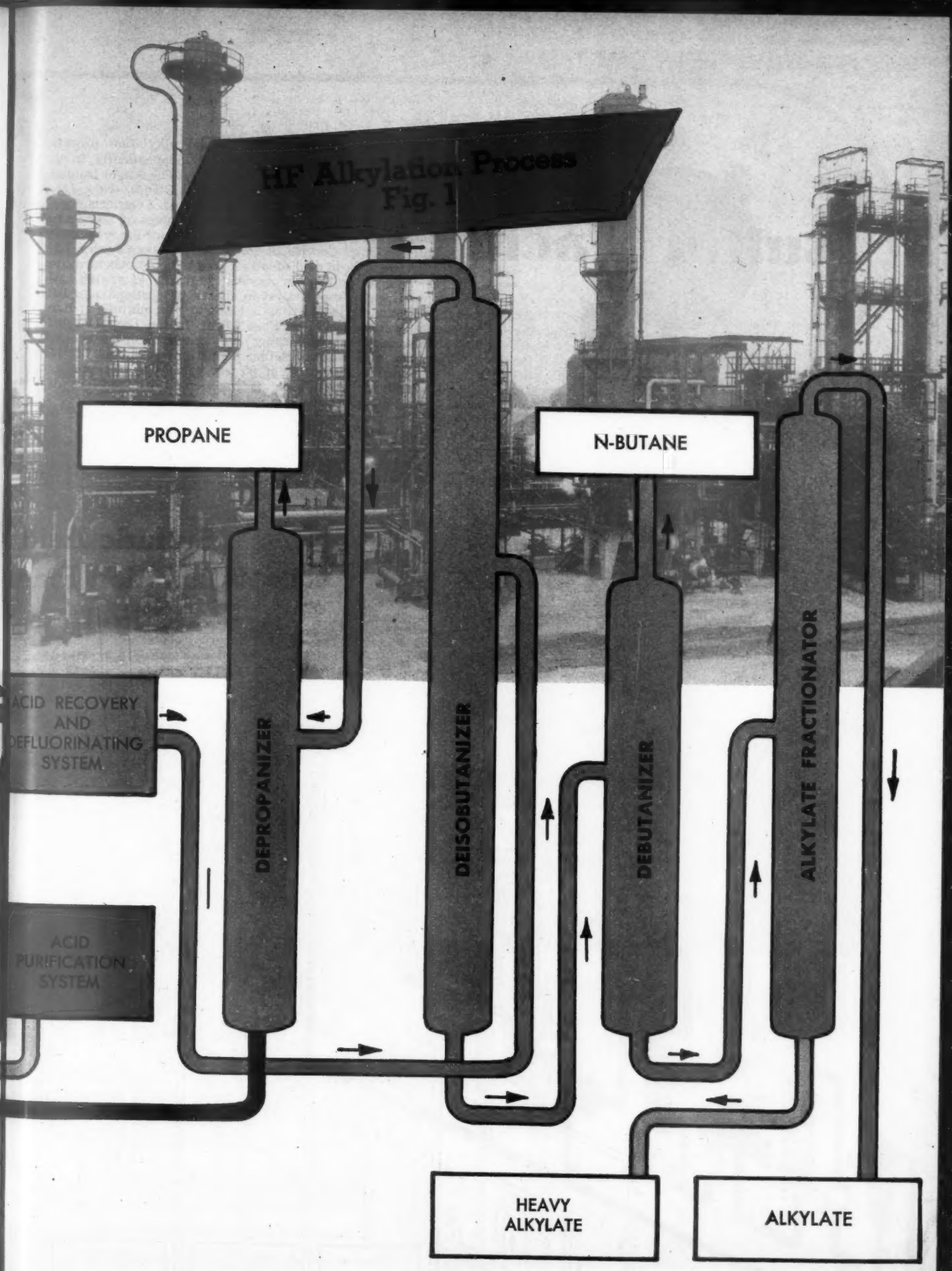
The data given in Table 1 are representative of a plant operation on alkylation of isobutane with butylenes and amylenes. Typical product inspections are shown in Table 2.

Cost of HF Alkylation

Average figures for direct operating costs are given in Table 3. An economic picture for any given case can be worked out once values are assigned for utility, feed stock, and labor costs.

Phillips Petroleum Co., and Universal Oil Products Co., license this process.



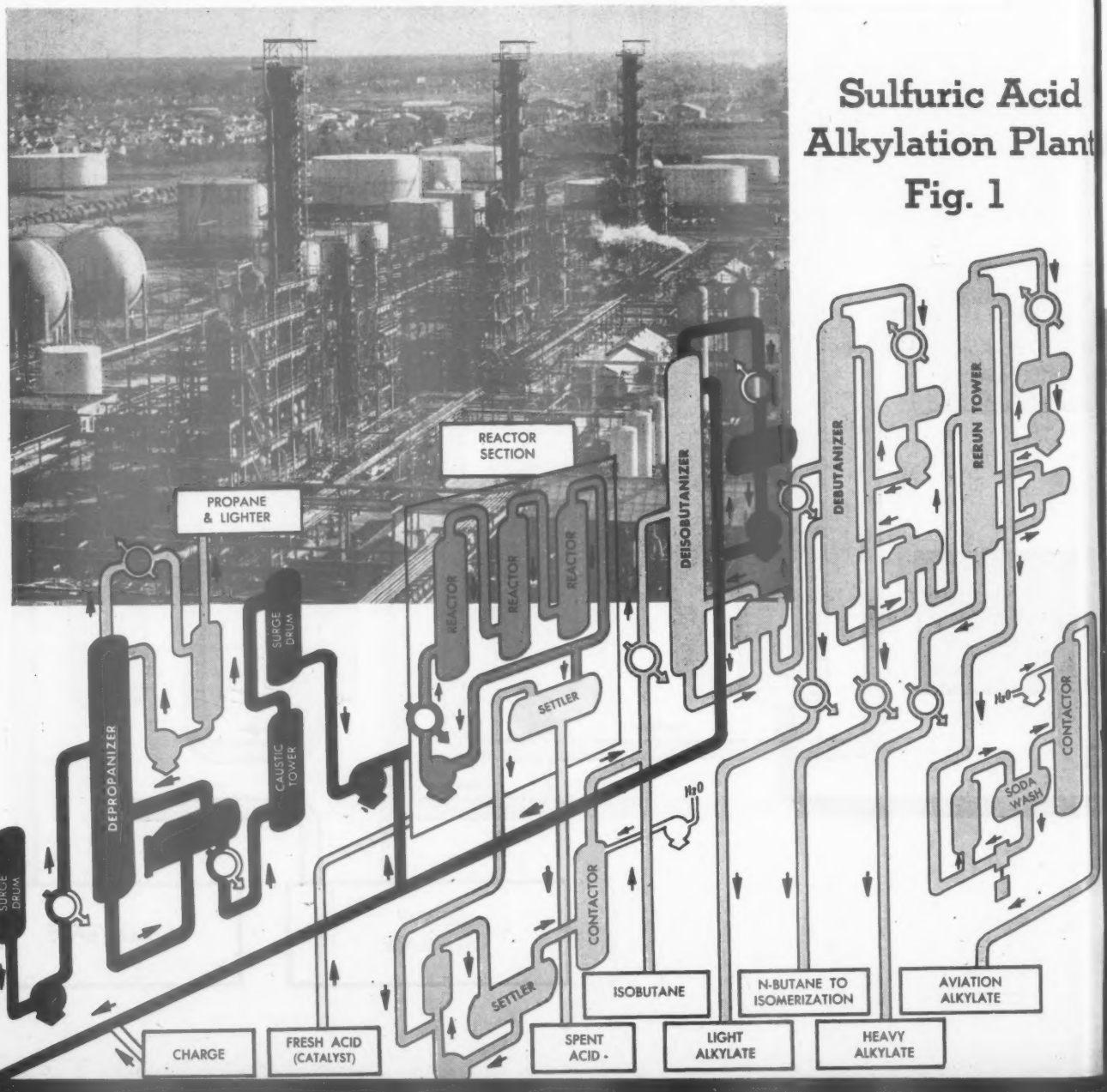

HF Alkylation Process
Fig. 1
PROPANE
N-BUTANE
ACID RECOVERY AND DEFLUORINATING SYSTEM
ACID PURIFICATION SYSTEM
DEPROPANIZER
DEISOBUTANIZER
DEBUTANIZER
ALKYLATE FRACTIONATOR
HEAVY ALKYLATE
ALKYLATE

sulfuric acid

THIS first practicable commercial alkylation process was developed by two groups, independently in at least the earlier stages, in the late 1930's—Anglo-Iranian Oil Co. of England, and the Standard Oil Co. (New Jersey)—M. W. Kellogg Co. and associated American companies. It has been used in a large number of units, the most recently built of which are the two at the war plant built by Cities Service Refining Co., at Lake Charles, La.

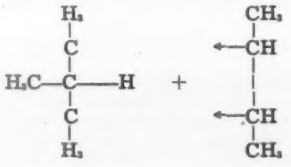
With sulfuric acid of above 90 per cent concentration as catalyst, the process consists essentially of mixing isoparaffins and the catalyst in chosen proportions, and introducing olefins such as butenes to this mixture at low temperatures, 50°-100° F. or lower. In the Lake Charles plant autorefrigeration by evaporation of part of the charge maintains a reaction temperature of about 35° F. The acid is generally of 98 per cent strength, and its strength during recycle is maintained by addition of more 98 per cent acid.

The reaction between the isoparaffin and olefin is

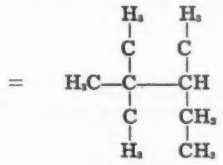


Sulfuric Acid Alkylation Plant
Fig. 1

one of addition, or "alkylation" as coined for this particular reaction. The olefin double bond breaks one bond, and attaches to the isoparaffin tertiary carbon by displacement on the one hydrogen thereon, which H attaches to the adjacent carbon of the olefin; the following equation indicates in general the reaction:



Isobutane Butene

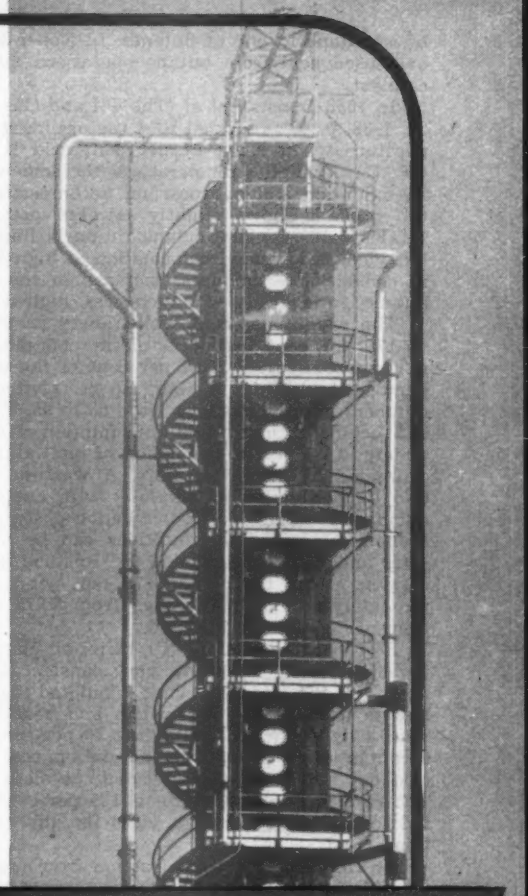


Isooctane (2,2,3-trimethylpentane).

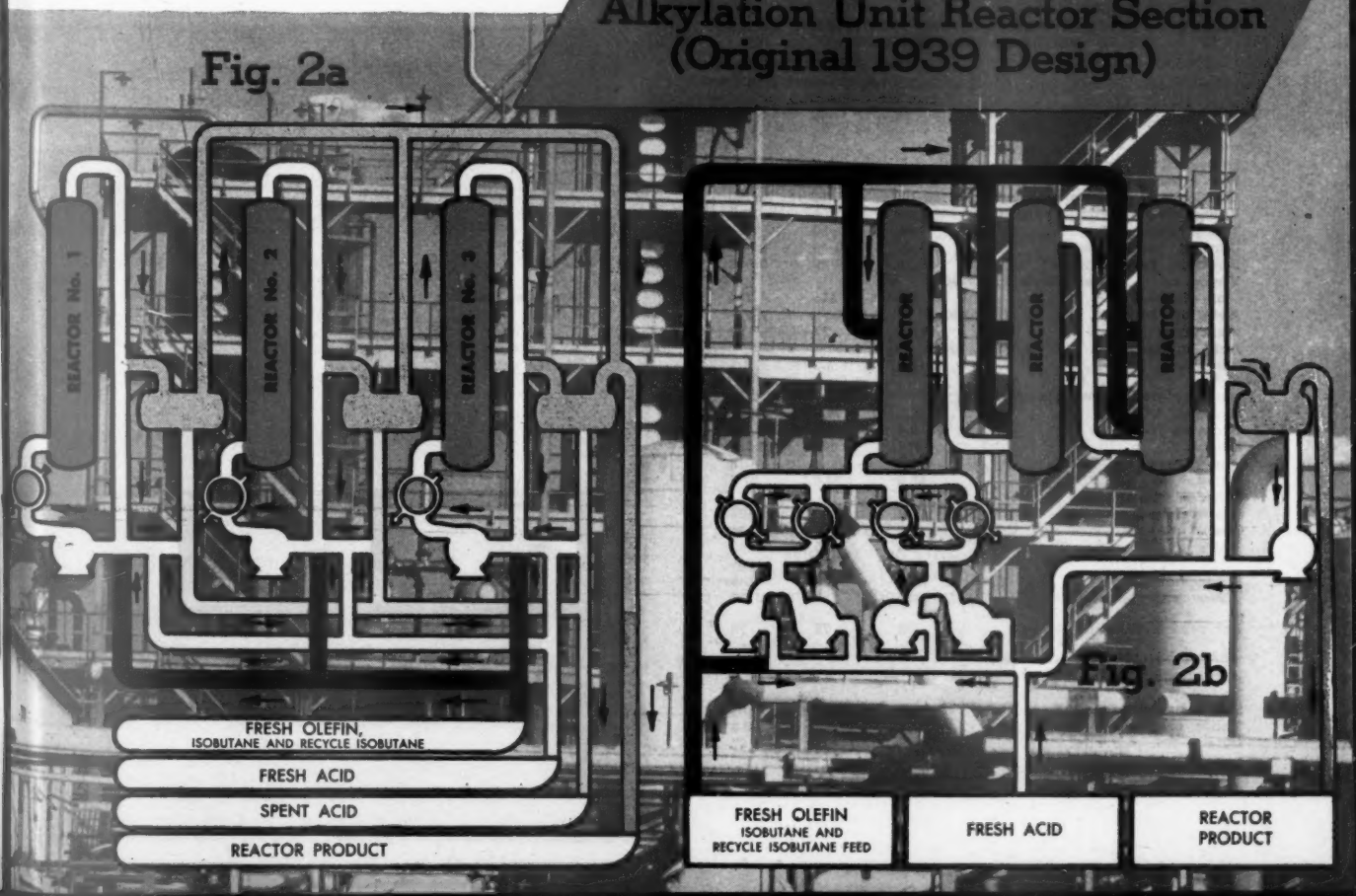
Substitution of isobutylene for butene-2 as the second reactant will yield 2,2,4-trimethylpentane, the standard "isooctane" rated at 100-octane number on standard scales.

Theory considers that the olefin is added to the acid, forming, for example i-butylsulfuric acid; because of the enhanced reactivity of the tertiary carbon of the isobutane it will combine with the olefin when the latter is attached to the acid catalyst, seizing one bond of the olefin, the hydrogen attached to this tertiary carbon combining with the bond released by the breaking of one of the double bonds of the olefin. By this reaction the intermediate olefin-acid compound is broken up, the acid is released and "regenerated" for further participation in the reaction as a carrier or catalyst. In practice the acid tends to carbonize small percentages of the charge, reducing the acid strength and fouling it to some extent so that the catalyst is finally reduced to a percentage too low for optimum use. It is thereafter either regenerated by conventional methods or is used for other purposes such as treating motor fuel or lubricating-oil fractions in the refinery.

In practical operations it is necessary to maintain a high ratio of isoparaffin to olefin. In isobutane alkylation this ratio is at least five mols



Alkylation Unit Reactor Section (Original 1939 Design)



of isobutane to one of butenes. In isopentane alkylation, once-used acid from butane operations may be used as catalyst.

In 1938 Dunstan et al (The Oil and Gas Journal, June 23, 1938, p. 49), reported that the optimum reaction temperature when using 97 per cent acid is about 20° C. (68° F.). At higher temperatures the acid is fouled rapidly, oxidation and hydrocarbon decomposition occur, and the product shows slightly lowered octane rating. At 14° F. (—10° C.), the octane rating is improved slightly but yield is lower with formation of high-boiling residue in considerable amounts. Increase in the isobutane-isobutene ratio leads to much less high-boiling residue.

The weight per cent yield ranges normally from 140 to 175 per cent based on olefin charged; theoretically it is approximately 203.7 per cent of the olefin charged. Lead susceptibility is high, 1.5 cc. giving 10-12 octane numbers improvement, as from 85 to 95, 87 to 98, 84.6 to 95.5 octane ratings. Acid consumption varies somewhat widely; 0.1 to 0.4 lb. per gallon of total alkylate has been estimated by some operators. A wartime unit reported 0.75 lb. per gallon of alkylate, with expectation of reducing this below 0.5 lb. per gallon postwar, when more economical operating conditions can be used. At these rates and with concentrated 66° Be. acid quoted in tank car lots at $15 per ton or 0.75 cent per pound, the cost for catalyst alone may range from 0.075 cent to 0.5625 cent per gallon of alkylate.

Results of alkylation with different charge stocks and under different conditions vary considerably as may be noted in the accompanying tabulated data. With isobutane used as the isoparaffin and reacting this stock with a light fraction containing 30 per cent olefins, predominantly propylene, the alkylation reaction was carried out at 85° F. and an isobutane-olefin ratio of 8:1. The resulting total alkylate is 185 per cent of the olefin fed to the reactor, a high yield for any of these operations.

By comparison a light fraction from cracked gasoline operations, containing 50 per cent mixed olefins reacted at 50° F. the yield was only 115 per cent of the olefin charged. In another case, reacting a charge containing 55 per cent olefins which were chiefly pentenes, with isobutane at 50° F. the yield was 134 per cent of the olefin charged. All yields are weight per cents. Correspondingly the alkylate from the propylene-containing charge showed more than 90 per cent of the total product in the aviation fraction boiling range, compared with 77 per cent of the mixed-olefins alkylate in the aviation range. The pentenes alkylate showed 90 per cent in the aviation range, an apparently high value since this is combining mainly C_5 olefins with isobutanes which can be expected to yield chiefly isononanes. In fact, the total alkylate shows at 446° F. end point, compared to 387° F. for the propylene-derived alkylate. In these cases the propylene alkylate showed 88 A.S.T.M. octane number, while the pentene-derived product shows 87 A.S.T.M.

TABLE 3—TYPICAL ALKYLATION CONDITIONS, YIELDS, PRODUCT PROPERTIES

	C_3 fraction from cracking	Light cracked gasoline	C_5 fraction from cracking
Wt. % olefin in stock	30	50	55
Conditions:			
Isoparaffin used	i-C_4	i-C_4	i-C_4
Mol. ratio, paraffin : olefin	8	8	8
Strength, % makeup acid	98-100	98-100	98-100
Volume ratio, acid : hydrocarbon	1	1	1
Temperature, °F.	85	50	50
Contact time, minutes	20-40	20-40	20-40
Strength, spent acid, wt. %	88-90	88-90	88-90
Yield, wt. %, total alkylate, based on olefin feed	185	115	134
Aviation fraction, wt. % of total alkylate	92-95	77	90
Acid makeup, lb./gal. of total alkylate	2.6	3.3	1.5
Total alkylate, C_5-free, properties:			
Gravity, °A.P.I.	72.1	70.6	76.6
Bromine No.	0.1-0.4	1-2	0.5-1.0
Sulfur, %	0.001	0.005	0.005
Vapor pressure, Reid	4	....	8
Octane No., A.S.T.M.	88.0	79.0	87.0
A.S.T.M. distillation:			
Initial boiling point, °F.	152	128	108
10% evaporated	180	162	144
50% evaporated	194	220	242
90% evaporated	271	328	306
End point	387	414	446
Per cent recovered	98	98	99
Per cent distilled at 266° F.	88	70	79
Properties of 300° e.p. fraction:			
Unsaturation	(*)	(*)	(*)
Sulfur, %	(*)	(*)	(*)
50% evaporated at, °F.	190	205	209
Vapor pressure, Reid	....	7.4	9.0
Octane No., A.S.T.M.	89	78	87

*Negligible.

TABLE 1—OPERATING DATA—ISOBUTANE-BUTYLENE FEED STOCKS

(Charge stocks may include isobutane mainly or isopentane and olefins such as propylenes, butylenes and amylenes)
(For 100 per cent design capacity operation)

Isobutane-olefin ratio in total reactor feed (volume)	3/1 to 8/1
Recycle isobutane purity, volume per cent	80-85
Acid-hydrocarbon ratio in reactor emulsion (volume)	0.8/1 to 1/1
Emulsion-olefin ratio (volume)	60-130
Reactor temperature (max.), °F.	35-70
Reactor pressure, psig.	150-175
Emulsion acid strength, weight per cent	88-94
Fresh acid makeup strength, weight per cent	98
Per cent total alkylate by volume on olefin in feed*	170
Per cent 360° F. end point aviation alkylate on total alkylate	95

*Including isopentane formed in process and allowing for some propylene and pentylene consumed by the acid.

TABLE 2—AVIATION ALKYLATE PRODUCTION

	Per cent of design cap.		
	40	100	150
A.S.T.M. clear octane rating	95.0	93.5	91.0
A.S.T.M. aviation octane +4.6 cc. TEL	110	108.0	107
°A.P.I.:	68-70		
R.v.p.	3.0	3.0	3.0
Bromine number	Nil	Nil	0.5
I.B.P., °F.	130	125	120
5 per cent at °F.	180	160	140
50 per cent at °F.	225	225	228
95 per cent at °F.	270	310	320
F.B.P., °F.	360	360	360

By means of sulfuric acid, technologists first alkylated isoparaffins commercially with olefins, which produced isooctane of 100 octane number if pure. Process reduces vapor pressure, retains octane rating.

isomerization

Hydrocarbons are isomerized with aluminum chloride for two purposes: to form isoparaffins for alkylation; to improve naphtha octane rating. Fairly pure fractions of normal paraffins are treated to make isoparaffins; naphtha mixtures are treated for general improvement.

TABLE 1 YIELDS AND PRODUCT PROPERTIES FROM HEXANE ISOMERIZATION, SINGLE-PASS AND RECYCLE OPERATIONS

	Yields			
Products—	Hexane feed	Once-through	Recycle, 1:1	Ratio, 2:1
Dry gas (vol. %)	....	1.8	3.6	5.3
Butanes (vol. %)	....	3.8	6.3	8.7
Isomerizate (vol. %)	....	96.8	87.2	85.2
Bottoms (vol. %)	....	....	7.0	6.2
Oct. Nos.; A.S.T.M., MM.	65.0	80.0	88.0	91.4
AFD 1-C method, +4 cc. TEL	87.0	100	100+1.5	100+3.5

TABLE 2 SINGLE PASS YIELDS IN BUTANE ISOMERIZATION

Product—	Yield, wt. %
Dry gas	0.7
Isobutane	50.6
n-Butane	48.8
Pentanes and heavier	0.7

TABLE 3 SINGLE PASS YIELDS IN PENTANE ISOMERIZATION

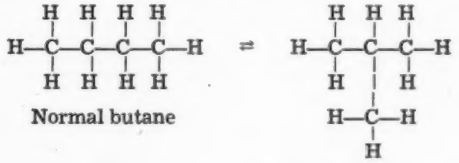
Product—	Yield wt. %
Dry gas	0.1
Butanes	1.7
Isopentane	83.0
n-Pentane	34.8
Hexanes and heavier	1.4

TABLE 4 EXPERIMENTAL LIQUID PHASE EQUILIBRIUM DISTRIBUTION OF BUTANES, PENTANES AND HEXANES IN MIXTURES AT VARIOUS TEMPERATURES

	Liq. vol., per cent			
Temperatures, °F.—	70	212	300	400
Butanes:				
Isobutane	85	75	65	43
n-Butane	15	25	35	43
Pentanes:				
Isopentanes	95	85	78	71
n-Pentane	5	15	22	29
Hexanes:				
Neohexane	57	38	26	21
2,3-Dimethylbutane	11	10	9	9
2-Methylpentane	20	28	34	36
3-Methylpentane	8	13	15	17
n-Hexane	4	11	14	17

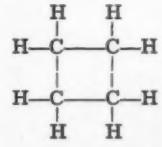
THE isomerization reaction has been recognized for a considerable time, but only in recent years has it been studied to the extent of determining the controlling factors in carrying out the reaction. Commercial units had been operated in a few instances prior to the start of World War 2, but the application of the process did not become general until need for isobutane for alkylate synthesis became critical.

The general isomerization reaction is essentially simple, being that of rearranging the carbon atoms in a molecule, a double bond, or other component part to yield a molecule of the same molecular weight and proportions of components but with a different, more complex structure. For example, in one of the simplest reactions, normal butane is rearranged to become isobutane, a more complex and more reactive molecule:



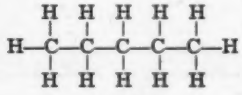
Normal butane ⇌ Isobutane

No carbon or hydrogen has been added to or lost from this molecule; whereas normal butane contains two primary carbons—attached to only one other carbon atom—and two secondary carbons—each attached to two other carbon atoms, isobutane has three primary carbons and one tertiary carbon, attached to three other carbons. It is to this tertiary carbon that the greatest reactivity of the isoparaffins is traceable. Butane can have three isomeric forms, normal butane and isobutane shown above, and the much less common one, cyclobutane, a relatively unstable compound in which the four carbons are joined in a ring structure:



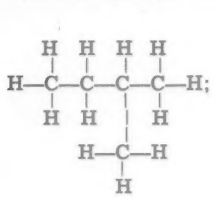
Strictly speaking, cyclobutane is not isomeric with the other two mentioned, having two less hydrogen atoms and being isomeric in this sense with butene. Butene has a double bond to account for its two fewer hydrogen atoms, whereas the ring structure causes the hydrogen shortage in cyclobutane.

Pentane may be found or synthesized in four molecular variations:

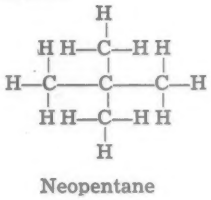


Normal pentane

the atomic proportions of the molecule:



Isopentane



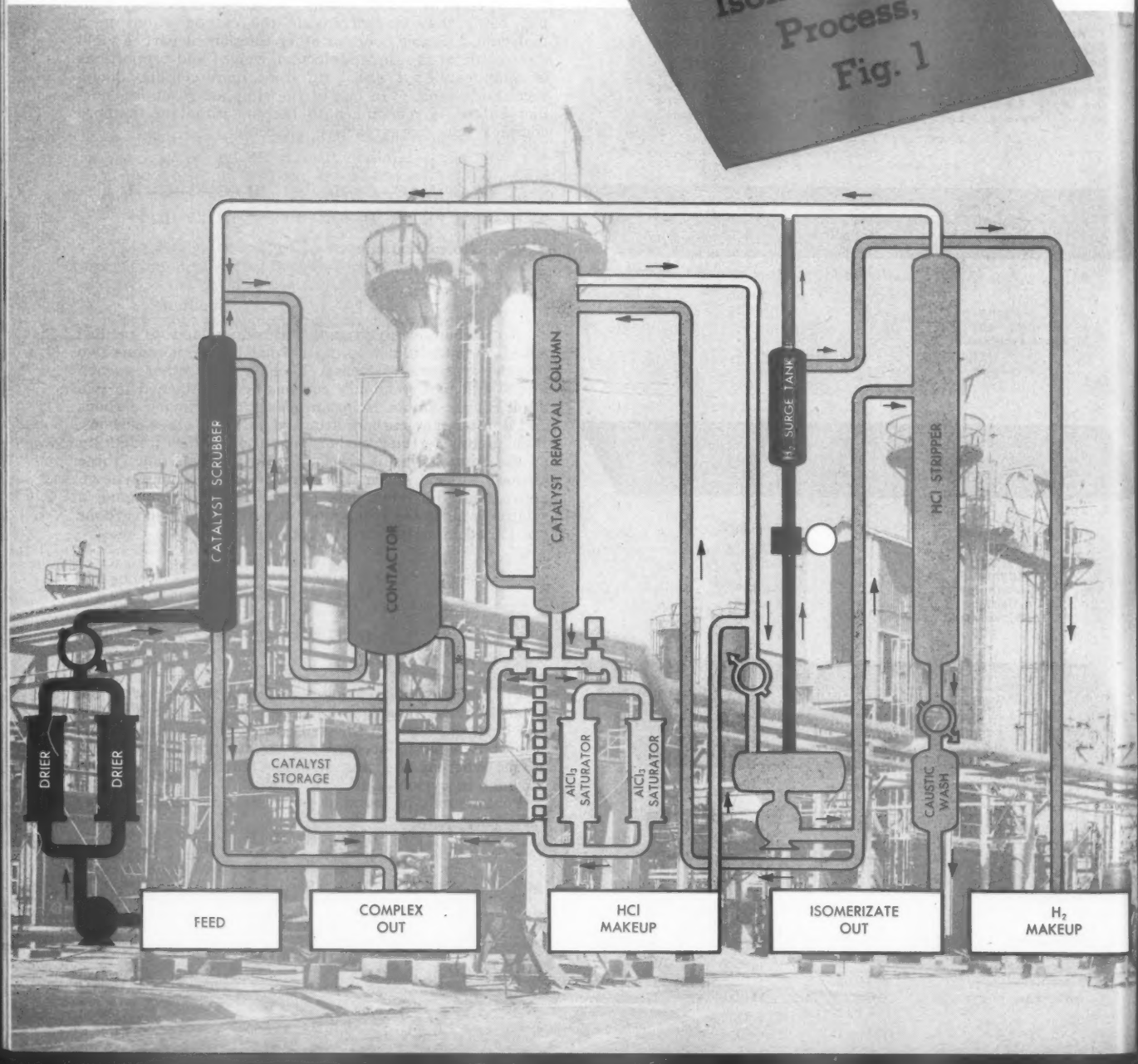
Neopentane

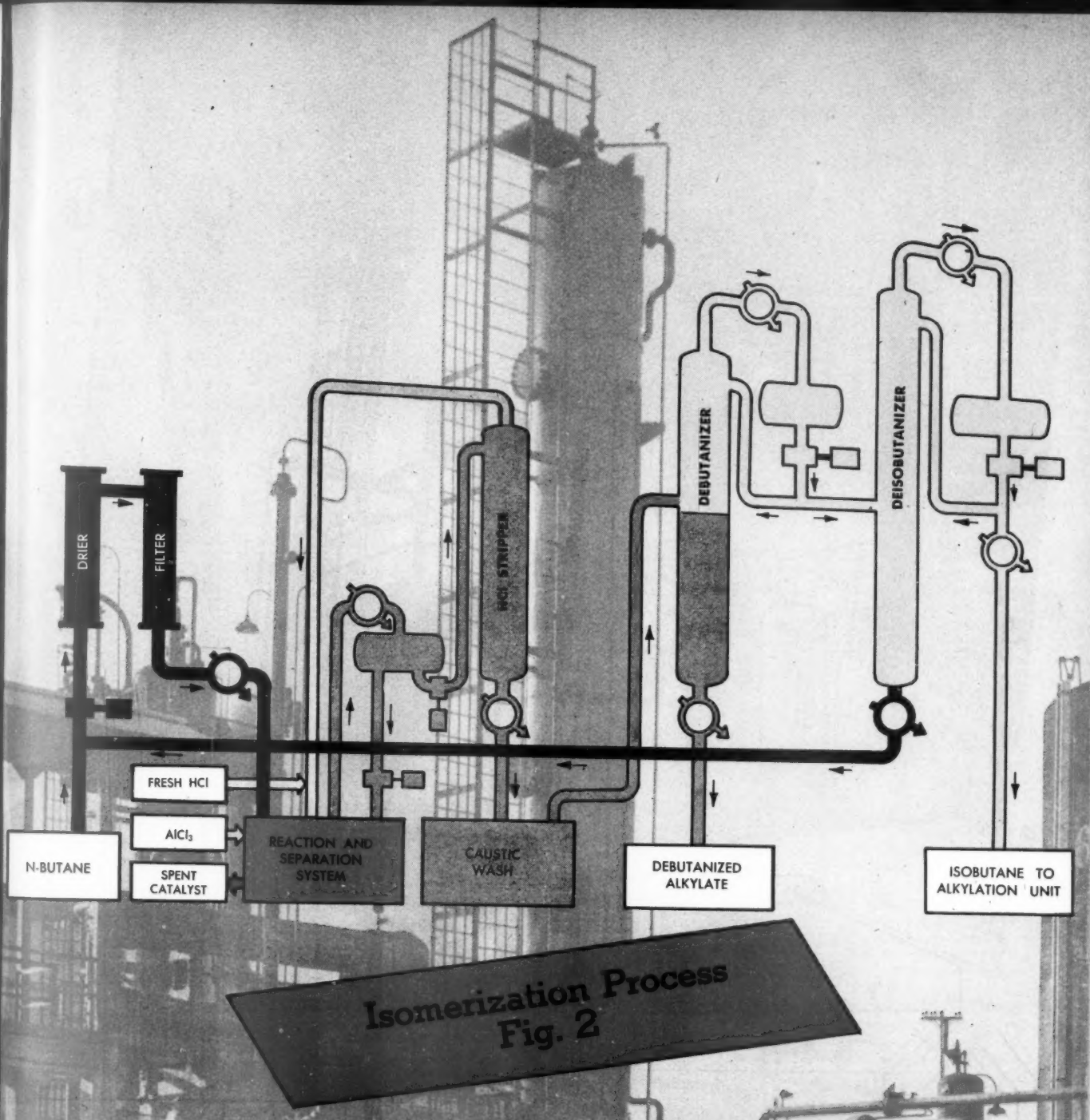
Neopentane is the smallest hydrocarbon molecule which can have the quaternary carbon attached to four other carbon atoms; and cyclopentane, having two fewer hydrogen atoms, is analogous to cyclobutane. Under isomerization conditions isopentane is formed usually in greatest percentage.

The most widely used catalyst for inducing the isomerization reaction is anhydrous aluminum chloride used in various forms. In one form it is supported on a carrier such as silica gel, or blocks or cylinders, or otherwise, so as to offer large areas for contact with the liquids or vapors to be reacted. One of the most effective is that of a relatively low melting-point mixture of $AlCl_3$ and $SbCl_3$, the latter antimony trichloride, which melts at 153° F. with 7.5 per cent of aluminum chloride in the mixture. With 0.5 to 2.0 per cent of $AlCl_3$ the melting point varies from 160° to 164° F. Another method of handling the catalyst is to impregnate a porous catalyst material with $AlCl_3$ and form the mixture into cylinders, blocks or other forms which bring the catalyst and reactant into contact in the reaction vessel, the catalyst remaining stationary. Dry hydrogen chloride, HCl, is added to the reactant liquid or vapor as catalyst promoter.

In a process such as the U.O.P. method for isomerizing normal butane a part of the charge stream is led to a saturator tower in which lump $AlCl_3$ is located, the tem-

Isomerization Process, Fig. 1





Isomerization Process
Fig. 2

perature being controlled to cause the butane to dissolve the required amount of the chloride; the remainder of the charge stream is heated to such temperature as to make the whole charge-catalyst mixture about 180° F. and this passes to the reactor, along with recycle and makeup HCl, thence to the chloride separator tower. Operating temperatures may vary between 170° and 210° F.; reactor pressures may range from 200 to 350 psig., or even may be held at other pressures, depending on the conditions of operation and the results desired.

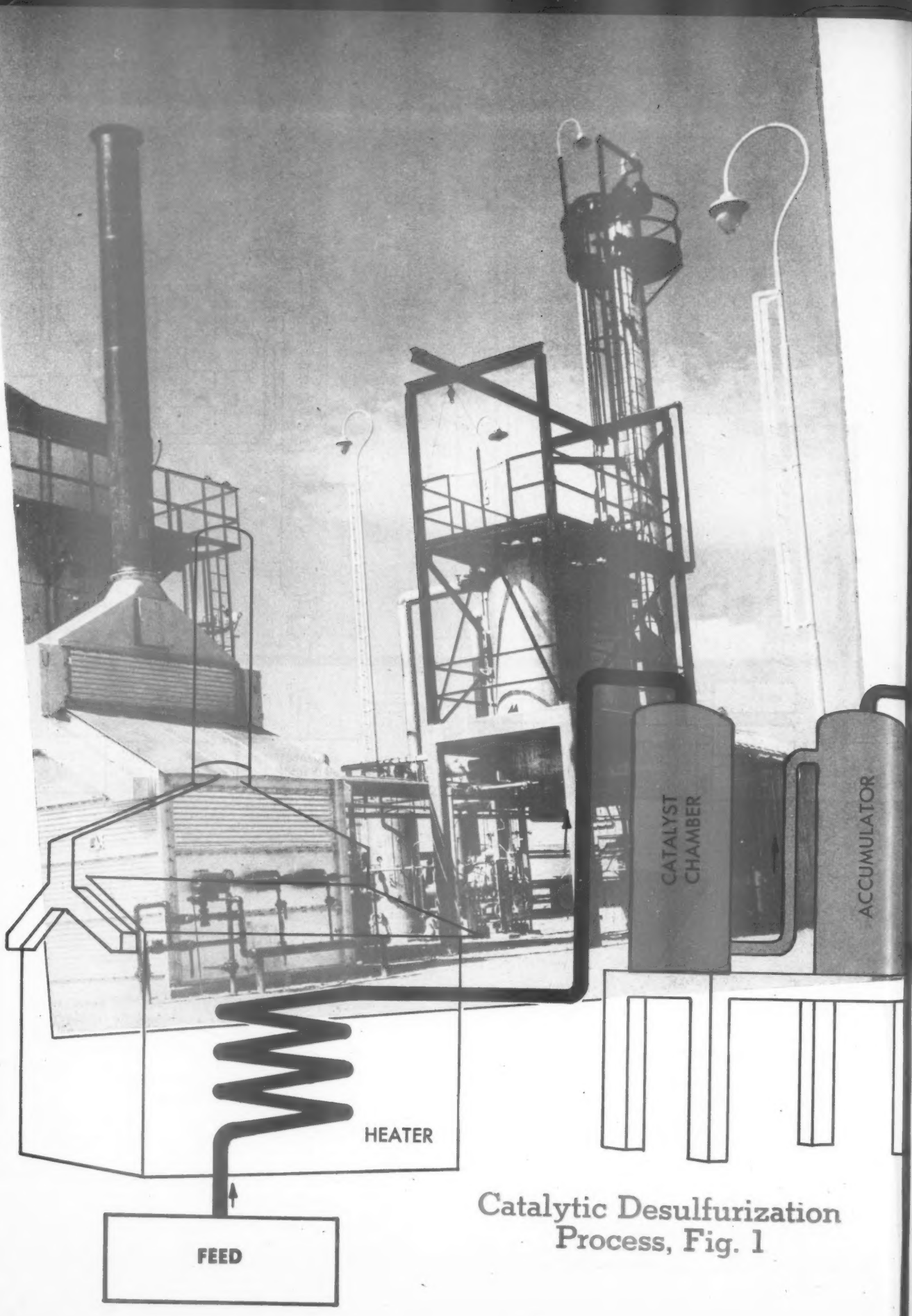
Liquid Phase Isomerization

Liquid phase isomerization of stocks such as normal pentane is carried out, for example with a liquid catalyst, $AlCl_3$-$SbCl_5$ with aluminum chloride 0.5 to 2.0 per cent of the mixture. Dry HCl is added up to about 5 mol. per cent of the feed, and the mixture heated to 180° F. and sent to the reactor, along with molecular hydrogen as a suppressor of cracking reactions, at a partial pressure of 60-70 psi. The reaction mixture is held at a total pressure up to 325 psig., and a 50 per cent conversion of butane, and up to 55-60 per cent of pentane is obtained per pass, which by recycle is raised to more than 95 per cent ultimate conversion.

Naphtha Isomerization

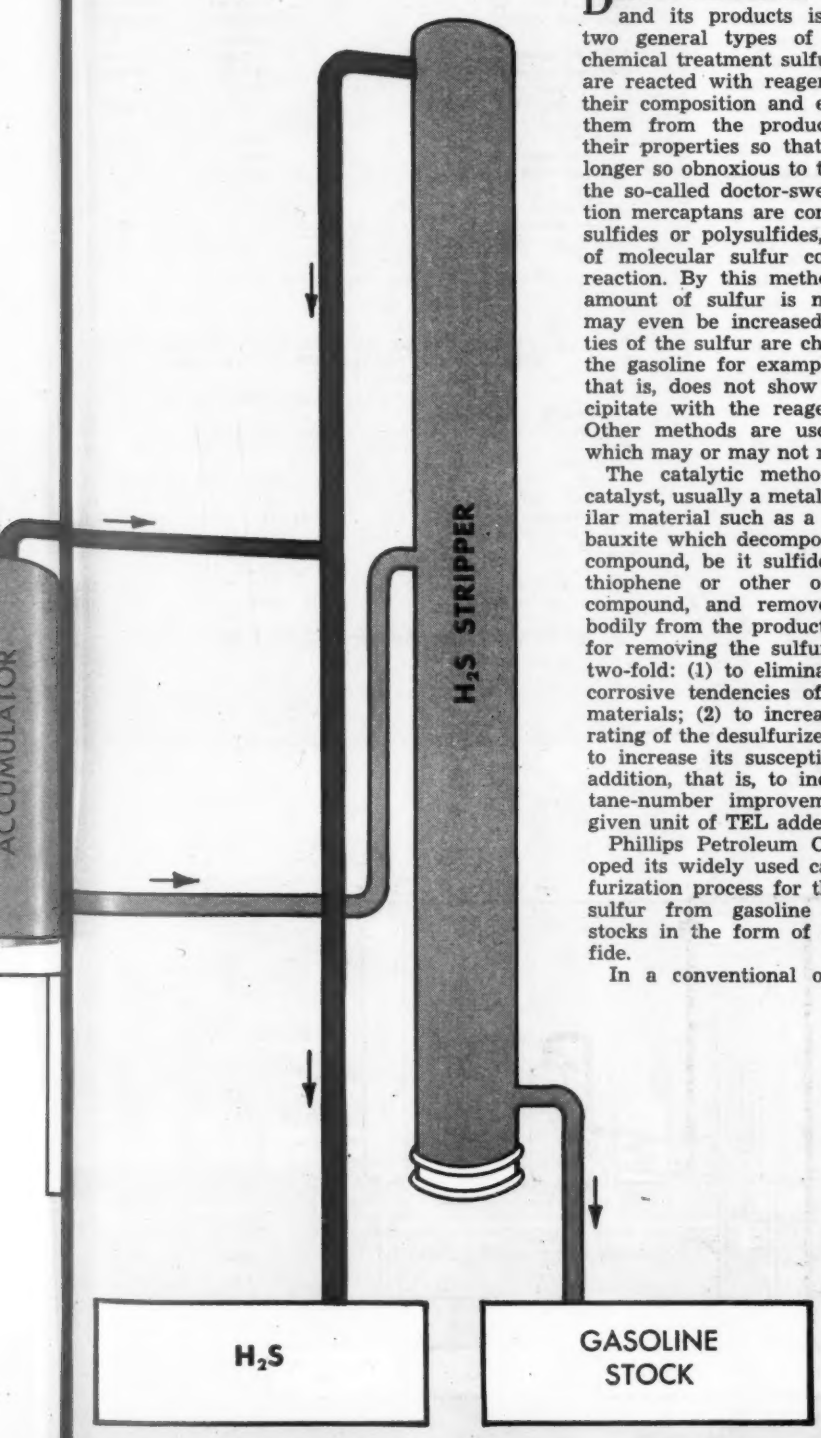
Mixtures of light hydrocarbons such as pentanes and hexanes, may be isomerized by the use of an $AlCl_3$ liquid complex in conjunction with HCl as promoter. Temperatures are normally held below about 200° F., while pressures are in the moderate range. The charge may be naphthas of various boiling ranges and the "isomate" or product may be raised in octane rating up to 20-25 numbers above that of the charge stock.

Universal Oil Products Co., Shell Development Co., and Standard Oil Co. of Indiana, license these processes.



Catalytic Desulfurization Process, Fig. 1

desulfurization



DESULFURIZATION of petroleum and its products is effected by two general types of process. By chemical treatment sulfur compounds are reacted with reagents to change their composition and either remove them from the product or change their properties so that they are no longer so obnoxious to the refiner. In the so-called doctor-sweetening reaction mercaptans are converted to disulfides or polysulfides, the addition of molecular sulfur completing the reaction. By this method the actual amount of sulfur is not decreased, may even be increased; the properties of the sulfur are changed so that the gasoline for example is "sweet," that is, does not show a black precipitate with the reagent employed. Other methods are used chemically which may or may not remove sulfur.

The catalytic method employs a catalyst, usually a metal oxide or similar material such as a filter clay, or bauxite which decomposes the sulfur compound, be it sulfide, polysulfide, thiophene or other organic sulfur compound, and removes the sulfur bodily from the product. The reasons for removing the sulfur entirely are two-fold: (1) to eliminate odors, and corrosive tendencies of many sulfur materials; (2) to increase the octane rating of the desulfurized product and to increase its susceptibility to TEL addition, that is, to increase the octane-number improvement for each given unit of TEL added.

Phillips Petroleum Co. has developed its widely used catalytic desulfurization process for the removal of sulfur from gasoline and kindred stocks in the form of hydrogen sulfide.

In a conventional operation, raw feed is picked up by a charge pump and passed to heat exchangers in heat exchange relationship with the catalyst tower effluent, thence to a tubular heater in which complete vaporization and superheating to about 750° F. is obtained. The superheated vapors then pass downward over the catalyst, contained in a catalyst tower, where the organic sulfur compounds are decomposed to the corresponding hydrocarbon and hydrogen sulfide. In this form, the sulfur is easily removed by caustic washing or other conventional means. Operating pressure for such a unit is of the order of 50-80 psi., and the flow ranges of 150 to 250 bbl. per ton of catalyst per day.

The materials for construction of such catalytic desulfurization units require no special corrosion-resistant qualities other than that necessary to combat the hydrogen sulfide evolved in the catalytic reactor.

Catalytic desulfurization is applicable to the treatment of light oils including liquefied petroleum gases, casing head or natural gasoline, certain reforming stocks, specification naphthas such as Stoddard solvent and painters' naphthas, straightrun and cracked gasolines. Except when treating cracked gasolines, catalyst life cycles are of the order of 3,000 to 15,000 bbl. per ton of catalyst.

For cracked gasolines, catalyst life cycles are in the range of 400 to 750 bbl. per ton of catalyst between regenerations. Recent commercial developments in the art of cracked-gasoline desulfurization are proving quite successful. This application of the Perco catalytic desulfurization process contemplates the regeneration of the catalyst in place by use of a diluent medium such as steam or fluegas and air. In such installation alternate catalyst towers would preferably be provided to allow for simultaneous regeneration and process operations. There are many obvious advantages of this type operation in addition to the reduced TEL costs and improved octane numbers, in that sweetening costs and attendant difficulties are drastically reduced and blending qualities improved.

There is no appreciable change in the composition of the desulfurized material other than the removal of organic sulfur, and the improvement of clear and leaded octane numbers as exemplified in the tables.

Perco Division, Chemical Products Department, Phillips Petroleum Co., licenses the process.

polymeriz

THE reaction of polymerizing light olefins to form heavier olefin molecules of lower vapor pressure, within the motor fuel boiling range, has been developed commercially over a period of 10 years or longer, and has become one of the standard refinery operations.

The most common catalysts for promoting polymerization are sulfuric acid, and forms of phosphoric acid. Phosphoric acid supported on an inert carrier such as magnesium sulfate is used. A pyrophosphoric acid salt, such as sodium pyrophosphate, is used also.

Two methods of handling this process are in use. One is called selective polymerization, wherein conditions are held so that only the isobutylenes are polymerized, yielding isooctenes, which may be hydrogenated later to isooctane. Much of this two-step product was made during the recent war as an aviation-gasoline component. Under other conditions other olefins such as propylene and pentenes are reactive, as well as normal butylenes and yield higher amounts of copolymers. Octane ratings of nonselective polymer may range up to 78-80 A.S.T.M. Motor Method. Isooctene (2,2,4-trimethyl pentene) is reported by Doss as showing 86 A.S.T.M. octane, clear, with about 100 Research, and a blending rating, in small percentages, of up to 150. This isooctene results, along with other isomeric octenes, from selective polymerization in large percentage, and is hydrogenated to isooctane or 2,2,4-trimethyl pentane, or "isooctane."

A typical flowchart for a two-step polymerization operation is shown in accompanying Fig. 1. The vapors are cooled to condense and remove water and pumped at 500 psig. to the reactors at 335° F. to promote formation of isooctene or selective polymer product. Effluent

TABLE 1—POLYMER MADE FROM PRODUCTS OF CRACKING NATURAL GAS C_3 AND C_4 FRACTIONS*

Inspection—	Before rerunning	After rerunning and treating
Gravity, °A.P.I.	64.8	66.1
R.v.p.	6.1	7.4
Doctor test	Positive	Negative
Corrosion test	Negative	Negative
Color	Blue	+28
A.S.T.M. gum	12.5 mg.	Trace
Oxygen induction period	45 min.	90 min.
Sulfur, per cent	0.018	0.018
Octane No. (L-3 method)	85.5	85.7
Distillation, (°F.):		
I.B.P.	100	100
10 per cent evap.	150	142
50 per cent evap.	220	220
90 per cent evap.	338	326
End point	450	394
Recovery, per cent	97	98
Loss, per cent	2	1

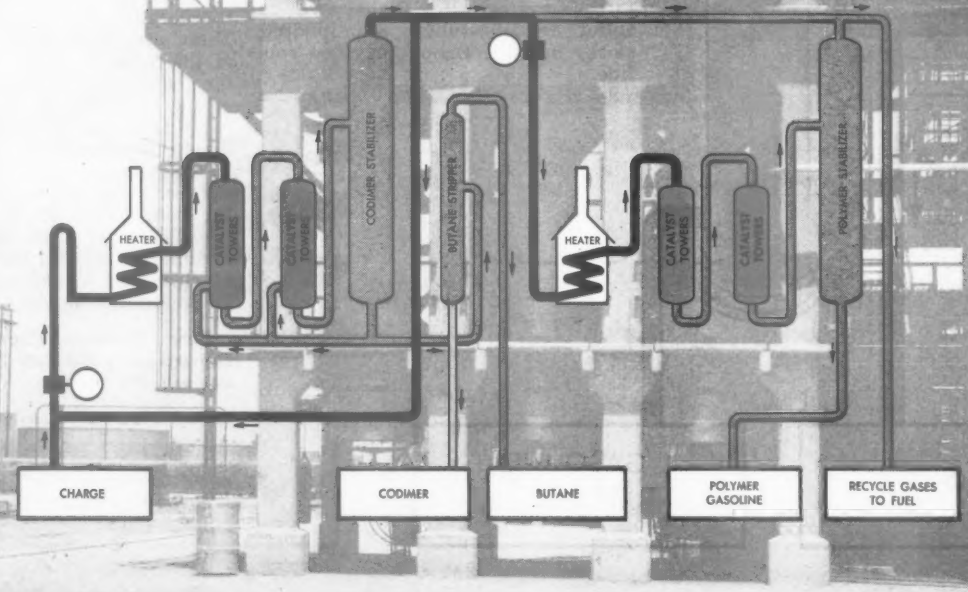
*The Oil and Gas Journal, May 4, 1939, p. 60.

TABLE 2—PROPERTIES OF RAW POLYMER, FROM "MIDGET" POLYMERIZATION PLANT OPERATIONS*

Inspection—	Plant number				
	1	2	3	4	5
Gravity, °A.P.I.	83.0	73.0	74.0	71.0	77.1
R.v.p.	20.5	24.1	25.0	28.9	30.3
Distillation, (°F.):					
I.B.P.	72	69	...	70	55
10 per cent evap.	102	123	...	100	90
50 per cent evap.	230	218	...	211	241
90 per cent evap.	...	...	...	341	450
End point	415	370	...	408	450
Recovery, per cent	93.5	87.5	...	94.5	75.1
Loss, per cent	6.0	11.0	...	4.2	23.2

*The Oil and Gas Journal, May 18, 1939, p. 123.

Polymerization Process, Fig. 1



product is refluxed to the reactors at various points to reduce the temperature, raised by the heat of reaction, to hold it at about 335° F. This step results in 1 to 2 per cent of polymer, called codimer. The unreacted olefins from this step, along with diluent gases and vapors, are recompressed to about 250 psig., heated to 450°-460° F. and contact the same catalyst in other reactor columns to produce additional, nonselective polymer. In case the separate yield of codimer is not wanted, the entire polymerization takes place in one step at the higher temperature and lower pressure given above, which reacts practically all olefins present. In any case, it is necessary to reflux either the polymerized product or some other coolant—cooled to 100° F. or thereabouts—to the reactors to control the temperature increase from the heat of reaction. Temperature may rise to about 480°-490° F.

In codimer formation up to 96-97 per cent of the butenes present (C_4 olefins) may be polymerized in a single pass through a battery of two or more reactor towers, operated in series. The surplus C_4s of a natural-gasoline fraction have been cracked to yield vapors containing about 24 per cent of olefins, and polymerized nonselectively at 250-275 psig. and 380°-410° F.

By polymerization of refinery gases containing olefins the total yield of motor fuel may be increased by 2 to 5 per cent. The blending octane value of the polymer in small percentages of the total motor fuel is much higher than that of cracked gasoline, and octane ratings of clear blends may be raised from 5 to 10 numbers, A.S.T.M. by the addition of the polymer.

Universal Oil Products Co., and M. W. Kellogg Co., license catalytic polymerization processes.

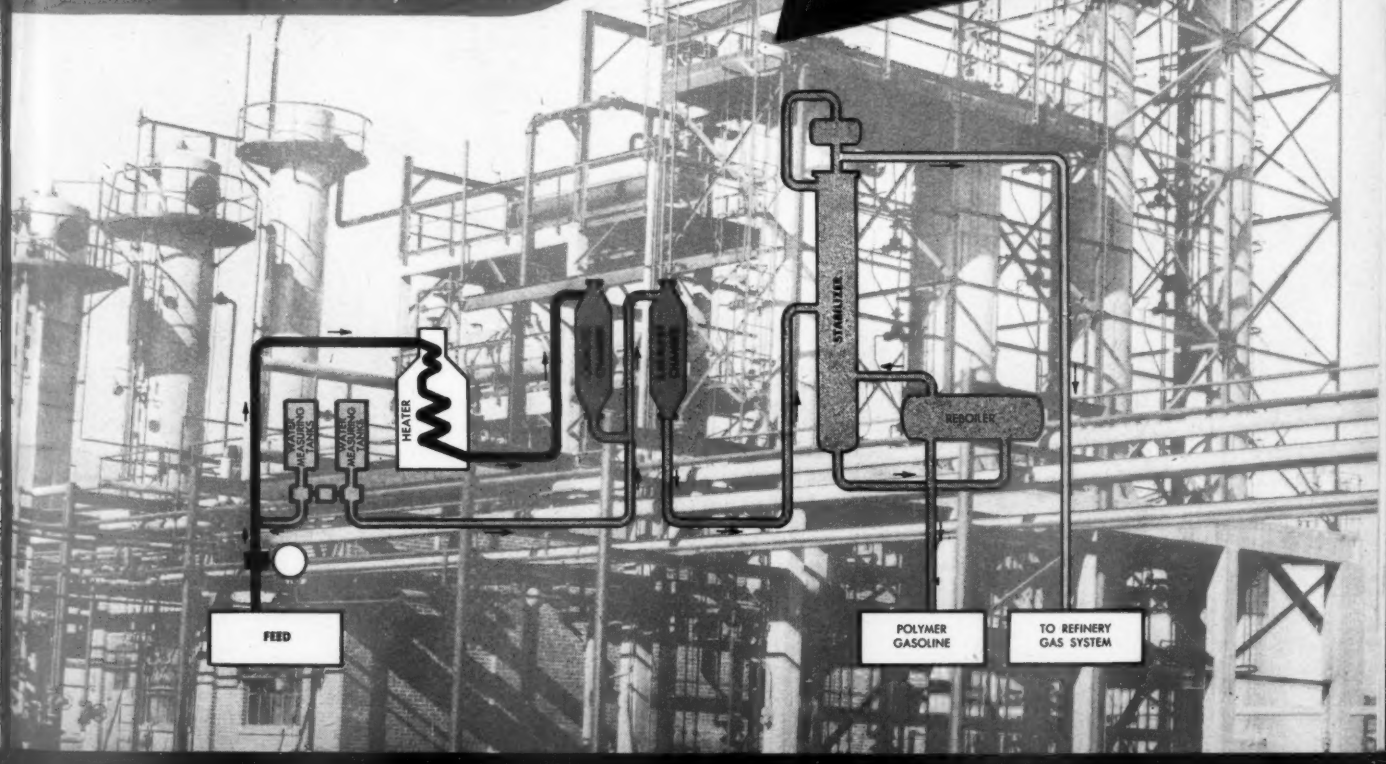
TABLE 3—EFFECT OF TEMPERATURE OF REACTION ON OLEFIN POLYMERIZATION

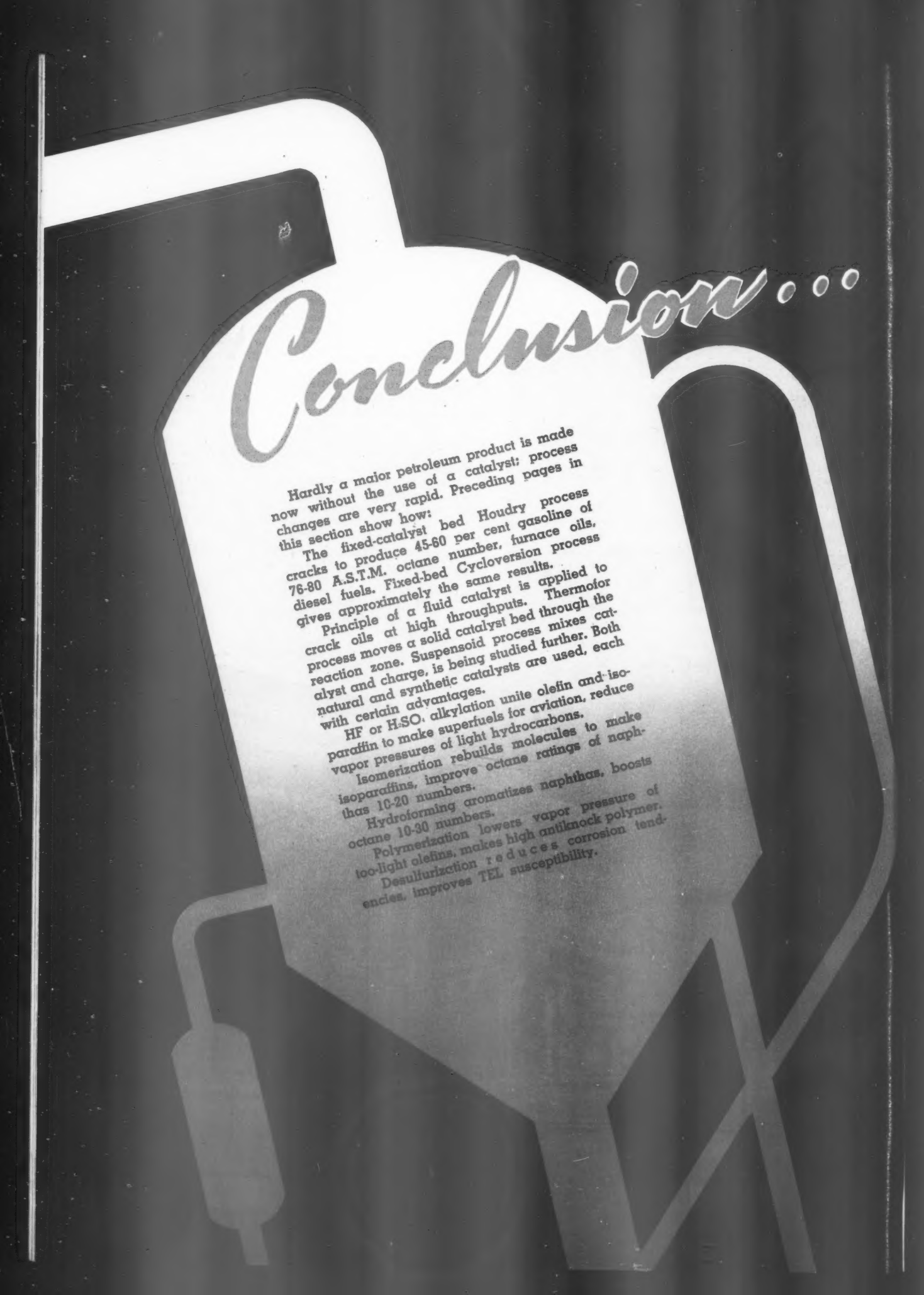
Avg. temp., °F., catalyst bed	Per cent olefin conversion
406	78.5
415	82.0
421	86.5
423	84.4
428	88.5
439	90.8
445	92.0
452	85.0

TABLE 4—INDUCTION PERIODS AND COPPER DISH GUM CONTENTS OF 35-50 BLENDS OF POLYMER GASOLINE AND STRAIGHTRUN NAPHTHA, WITH DIFFERENT INHIBITORS*

		TEL, cc./gal.			
Inhibitor—	Lb./1,000 bbl.	0	1	2	3
		Induction period, hours			
AO-3	10.00	5.25	5.75	6.00	5.00
AO-6	11.42	6.75	6.50	7.00	6.75
AO-14	11.42	4.00	4.50	4.00	5.25
UOP-4	8.00	5.50	6.25	....	....
G-10	4.00	4.25	4.50	4.25	4.25
		Copper dish gum			
AO-3	10.00	13.0	13.0	20.5	15.0
AO-6	11.42	....	7.0	....	33.0
AO-14	11.42	....	12.0	....	35.0
UOP-4	8.00	....	16.0	....	35.0
G-10	4.00	....	17.0	....	36.0

*The Oil and Gas Journal, March 23, 1939, p. 107.





Conclusion...

Hardly a major petroleum product is made now without the use of a catalyst; process changes are very rapid. Preceding pages in this section show how:

The fixed-catalyst bed Houdry process cracks to produce 45-60 per cent gasoline of 76-80 A.S.T.M. octane number, furnace oils, diesel fuels. Fixed-bed Cycloversion process gives approximately the same results.

Principle of a fluid catalyst is applied to crack oils at high throughputs. Thermofor process moves a solid catalyst bed through the reaction zone. Suspensoid process mixes catalyst and charge, is being studied further. Both natural and synthetic catalysts are used, each with certain advantages.

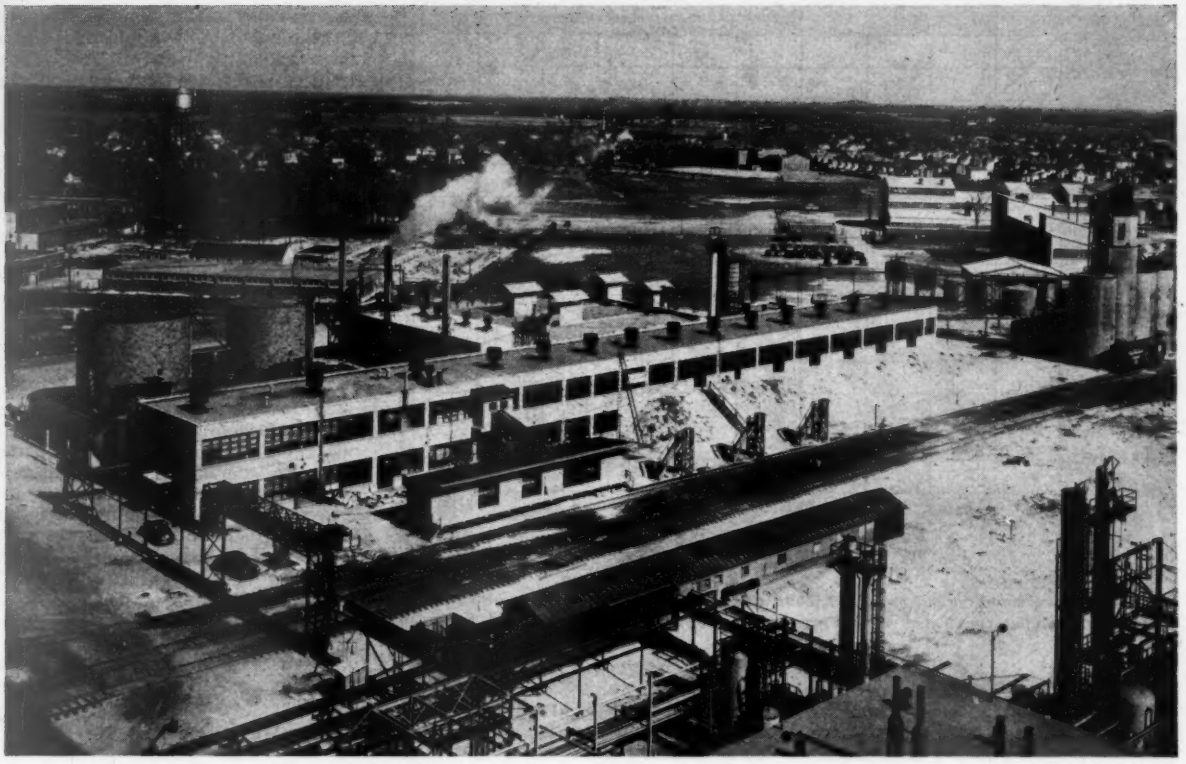
HF or H_2SO_4 alkylation unite olefin and isoparaffin to make superfuels for aviation, reduce vapor pressures of light hydrocarbons.

Isomerization rebuilds molecules to make thas 10-20 numbers.

Hydroforming aromatizes naphthas, boosts octane 10-30 numbers.

Polymerization lowers vapor pressure of too-light olefins, makes high antiknock polymer.

Desulfurization reduces corrosion tendencies, improves TEL susceptibility.



View of bead-catalyst manufacturing plant located at the Paulsboro (N. J.) refinery of Socony-Vacuum Oil Co. Chemical storage tanks at extreme left, buildings housing manufacturing equipment in center, and finished-catalyst storage silos at extreme right

Comparison of Bead And Clay Catalysts

For Peacetime Operation of Plants For Motor Gasoline, Other Products

by L. P. Evans*

SUMMARY

Four to eight per cent more 10-lb. R.v.p. motor gasoline may be produced under the same general operating conditions by use of bead catalysts, compared with clay catalyst yields in operating a Thermofor (T.C.C.) cracking unit, this article shows. Clay catalyst tends to be poisoned by charge stocks high in sulfur and nitrogen compounds, sometimes to a prohibitive rate of decrease in gasoline yield and increase in gas and coke formation, whereas bead catalyst is not affected in its efficiency by such stocks. Generally, sweet stocks do not poison either catalyst appreciably. Recent advances in bead manufacture, raising the sodium content of the catalyst, improves the aging properties. Octane rating, A.S.T.M. clear, of bead-catalyzed motor fuel is higher than that made with clay catalyst by values ranging from 0.4 octane number on Mid-Continent gas oil to 2.6 from mixed-base gas oil. A high-sulfur stock from California shows no gain in octane rating, clear, but with 3 cc. of TEL an advantage of 0.9 octane number increase is obtained.

DURING the war the use of the bead catalyst[1] was broadly accepted by refiners using the T.C.C. process[2] for manufacturing aviation gasoline base stock for 100-octane number aviation-gasoline production. The chief advantage which beads offered over the natural catalyst originally developed for this process was the possibility of greatly increasing octane quality and production of the essential base stock from a given plant without any changes or additions to plant equipment. So important was this advantage in the critical stages of the war that top priority was assigned to the construction of bead catalyst manufacturing facilities, the full production of which was used to equip all subsequent T.C.C. installations and as many of the older plants as possible. Thus, at the end of the war, about half of the total T.C.C. installations in this country were operating wholly or in part on bead catalyst. The success with which this catalyst fulfilled its wartime role is now a matter of history.

Today, with catalytic cracking recognized as being an equally important

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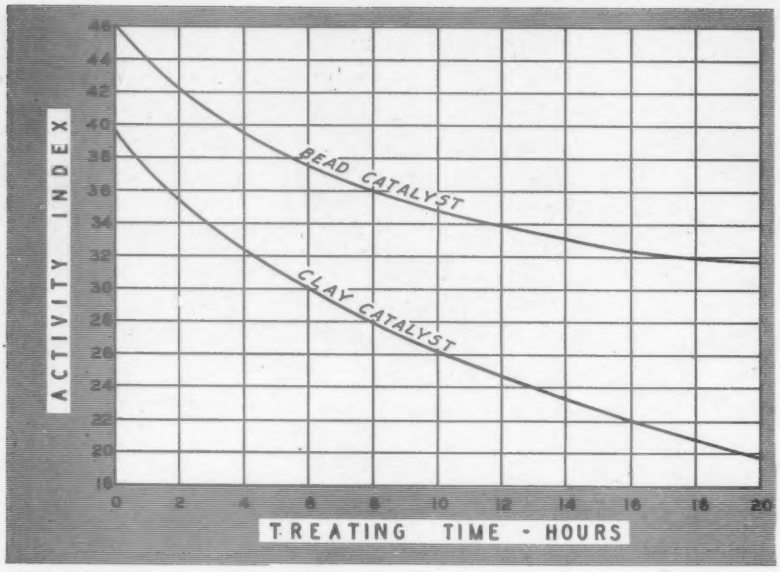


Fig. 1—Relative steam stability of fresh bead and clay catalyst under accelerated aging conditions. Treating conditions: 40 per cent steam, 60 per cent air at 1,400° F. and 1 atmosphere

asset in postwar refinery operations for motor-gasoline production,[1] refiners possessing T.C.C. plants as well as those planning new T.C.C. installations are interested in knowing the relative merits of the two catalysts now available to them. This can be appreciated from the fact that the T.C.C. plant will generally produce from 20 to 50 per cent of the total motor gasoline output of a given refinery and any flexibility and economy which can be realized in the T.C.C. operation through proper choice and use of catalyst is bound to reflect in improved over-all refinery position.

Although the choice between clay and bead catalyst is ultimately dictated by economics, it is possible to draw comparisons of some of the more important factors which enter into the complete evaluation of the two catalysts. This has been done in the following discussion, which represents the results of an extensive analysis of commercial T.C.C. data, supplemented by more accurate laboratory investigations in T.C.C. pilot units which duplicate commercial operation. Economic comparisons on an arbitrary basis for a few typical stocks are included.

Catalyst Cost

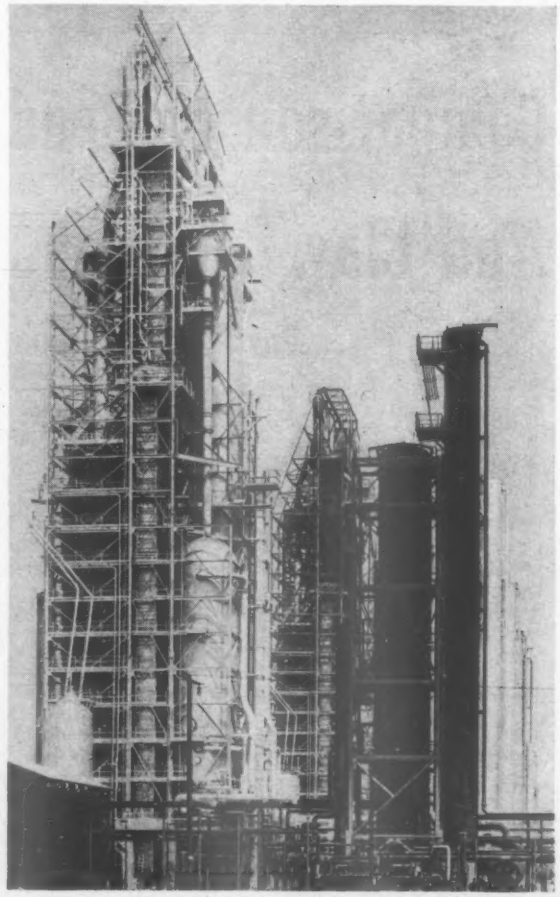
By catalyst cost is meant the cost of catalyst required to maintain the T.C.C. plant in continuous operation. It resolves itself into two factors: daily catalyst makeup rate and price of catalyst. Clay catalyst, as purchased, is priced at $80 per ton (f.o.b. catalyst manufacturing plant) which, after allowance for 20 per cent moisture content, is equivalent to $100 per ton on a dry basis. The purchase price for beads, which are sold in dehydrated form, is $240 per ton. This, incidentally, is the lowest price ever known to be quoted on a pure synthetic-cracking catalyst.

Regarding the factor of catalyst makeup requirements, commercial experience has proven that with good average operation the makeup rate for beads can be maintained at 1 to 1½ tons per day on a nominal 10,000-bbl.-per-day unit. The corresponding rate for clay is of the order of 3 to 4 tons per day.

The difference in makeup requirements noted is due chiefly to the better physical characteristics inherent in the bead particles, although other considerations, such as maintenance of reasonable activity level also govern the minimum makeup rates used commercially. Two of the most important physical properties affecting catalyst losses are attrition resistance and crushing strength, in both of which, according to standard laboratory tests, bead excels by a considerable margin.

From the above considerations it becomes evident that while the price of beads is roughly three times that of clay on a unit weight basis, this is offset by correspondingly lower makeup requirements, resulting in about equal daily makeup cost for the two catalysts. This is a significant point, and one which has an important bearing on the final economic evaluation of the two catalysts.

The foregoing does not, of course, take into account the higher cost for initial catalyst charge when using beads. For a nominal 10,000-bbl.-per-day plant with 400 tons catalyst inventory, this incremental cost for beads will amount to about $65,000. However, it is normally not necessary to replace the catalyst fill in a T.C.C. plant except through the process of daily makeup already described. Consequently, this cost factor is essentially an investment rather than an operating item and, as will be shown later, becomes of minor importance in any long range economic comparison of the two catalysts.



First units to employ bead catalyst. View of one end of battery of four T.C.C. units at the Torrance (Calif.) refinery of General Petroleum Corp., having total nominal charge capacity of 40,000 bbl. per calendar day

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Equilibrium Activity

Equilibrium activity represents the steady activity level which a catalyst attains in a given plant as a result of a balance between the progressive aging tendency of the catalyst already in service and the fortifying effect of fresh catalyst additions. This aging tendency is characteristic of all cracking catalysts and depends to a great extent on the intrinsic stability of the catalyst toward temperature and steam, the two factors which cause normal aging in the catalytic process.

Beads exhibit better stability with respect to high temperatures and with respect to steam at the higher temperature levels, where the action of steam becomes very pronounced. The thermal stability of beads is demonstrated by the fact that this catalyst can be heated safely in air to temperatures of 1,700° F., whereas clay catalyst begins to deteriorate markedly above 1,450° F. The relative steam stability of the two catalysts is illustrated in Fig. 1.

Since bead catalyst starts with a higher initial activity than clay catalyst and at the same time possesses better aging characteristics, it would be expected to maintain a higher equilibrium activity than clay under comparable conditions of operation. That this actually occurs in practice is already well substantiated by commercial T.C.C. experience. Thus the clay plants operating with nominal makeup rates of 3 to 4 tons per day show equilibrium activity levels in the range of 29 to 32; while the bead units, even with makeup requirements of the order of 1 to 1½ tons per day, maintain equilibrium activity at 34 to 37, or about four points higher than clay. Incidentally, the fact that activity levels and attrition rates of this order of magnitude can be maintained commercially on both types of catalyst is significant and is a reflection of the soundness of the design and operating principles embodied in the T.C.C. process.

Fig. 2 shows how the equilibrium activity increases with increase in makeup rates above the normal level for each catalyst. These curves represent the best correlation of available commercial data and have been adequately checked by the laboratory aging tests. They can be used as a guide in evaluating the incremental cost of maintaining a higher level in a given plant.

TABLE 1—COMPARISON OF PRODUCT YIELDS FROM BEADS AND CLAY CATALYSTS AT NORMAL AND HIGH COKE LEVEL
(T.C.C. Pilot Plant Data)

Stock—	Mid-Continent gas oil			
Gravity, °A.P.I.	28.3			
Aniline No., °F.	188			
Boiling point, °F.	522-970			
	Normal coke level operations		High coke level operations	
Catalyst—	Clay	Bead	Clay	Bead
Average cracking temperature, °F.	890	830	870	815
Space velocity, V/Hr./V	1.8	1.8	0.6	0.6
Catalyst to oil ratio, V/V	1.8	1.8	1.8	1.8
Coke laydown, lb./hr./10,000 B/D feed	3,600	4,250	6,000	6,500
Yields:				
Cycle stock above motor gasoline, % vol.	55.4	50.8	47.0	37.4
C_5-free 375 at 90% motor gasoline, % vol.	36.1	40.2	39.3	47.4
NC_4, % vol.	1.1	1.9	1.5	2.7
IC_4, % vol.	2.4	5.5	3.6	9.7
C_4=, % vol.	4.7	3.9	5.7	3.9
C_5-free liquid recovery, % vol.	99.7	102.3	97.1	101.1
Dry gas (C_3 + lighter), % wt.	5.6	4.1	7.3	5.9
Coke, % wt.	2.8	3.3	4.6	5.2
Conversion (100 minus cycle stock), % vol.	44.6	49.2	53.0	62.6
10-lb. R.v.p. motor gasoline, % vol.	38.5	42.6	41.7	49.6
Excess C_4 above 10-lb. R.v.p., % vol.	5.8	8.9	8.4	14.1
Incremental 10-lb. motor (beads over clay), % vol.	....	4.1	....	7.9
Incremental excess C_4 (beads over clay), % vol.	....	3.1	....	5.7
Incremental conversion (beads over clay), % vol.	....	4.6	....	9.6

Product Yields

In this and all subsequent comparisons drawn herein between clay and beads, consideration will be confined to "equilibrium" catalysts and, except where noted, to operations which fall within the scope of present commercial practice. One of the chief factors governing the performance of a given T.C.C. plant is that of coke burning capacity. Nominal 10,000-bbl.-per-day plants have coke burning capacities between 4,000 and 5,000 lb. per hour, depending on the exact size and design of the kiln. Consequently, in comparing catalyst performance, it is assumed that cracking conditions are adjusted as nearly as possible to obtain optimum production within these prescribed coke limits.

Regarding yield comparisons, both laboratory and plant data on equilibrium catalysts show that relative yields vary with the type of stock but that in general, beads yield a more favorable product distribution than clay. Thus, with beads the motor-gasoline yield, based on charge, is from 1 to 4 per cent higher, excess butane also several per cent higher, the dry gas production about the same or less, and the resulting over-all recovery of liquid products higher. The incremental C_4 yield from beads is largely isobutane, while the butylene (and propylene) yields are only slightly lower than from clay.

Data illustrating these yield differences on a typical Mid-Continent stock are shown in the first two columns in Table 1. The figures indicate that the substitution of beads for clay in a 10,000-bbl.-per-day plant cracking this stock will produce 410 bbl. per day more 10-lb. R.v.p. motor gasoline; 310 bbl. per day more excess butane above vapor pressure requirements, and 260 bbl. per day more of total liquid products. The corresponding conversion is 4.6 per cent higher for bead operation.

In comparing the above operations on the two catalysts, it will be noted that beads, by virtue of their higher activity, require less severe cracking conditions to effect the same conversion as clay. This is an incidental advantage which can be reflected in reduced plant maintenance and process fuel cost.

It may be of further interest to note that the yield advantage of beads over clay catalyst could be increased

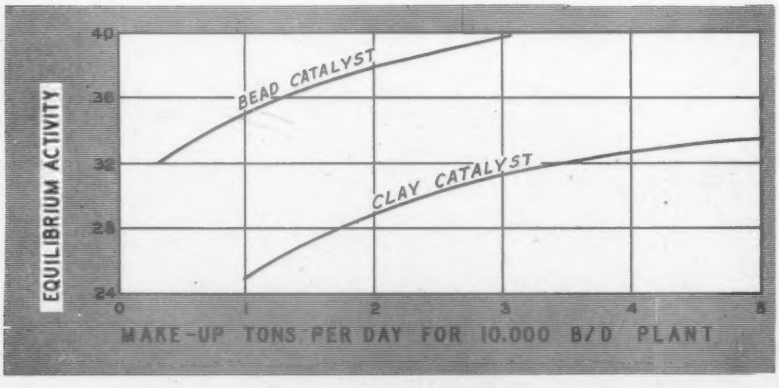


Fig. 2—Relation between equilibrium activity and catalyst makeup requirements in T. C. C. plants operating on clay and bead catalyst

TABLE 2—COMPARISON OF MOTOR GASOLINE QUALITY* FROM BEAD AND CLAY CRACKING OF VARIOUS STOCKS

Charge stock—	East Texas gas oil		Mid-Continent gas oil		Coastal gas oil		Mixed base gas oil		Wilmington gas oil		West Texas visbreaker gas oil	
°A.P.I.	28.7		28.3		24.3		26.5		20.8		32.4	
Aniline No., °F.	188		188		166		160		132		128	
Sulfur, wt. %	0.25		0.41		0.21		0.97		1.8		1.19	
Boiling range, °F.	475 to 935		522 to 970		512 to 925		445 to 1,025		533 to 950		327 to 703	
Catalyst—	Clay	Beads	Clay	Beads	Clay	Beads	Clay	Beads	Clay	Beads	Clay	Beads
Properties of 10-lb. motor:												
°A.P.I. gravity	59.2	62.0	58.7	59.9	57.0	58.1	55.6	55.9	53.6	53.7	56.2	56.1
Acid heat, °F.	76	34	137	88	38	35	124	107	150	108	72	49
Sulfur, % wt.	....	....	....	....	....	....	0.32	0.23	0.80	0.38	0.09	0.10
O_2 bomb induction, hrs.:min.	16:40	>19:00	6:30	17:45	20:00	>20:00	....	....	4:50	6:30	>20:00	>20:00
A.S.T.M. distillation:												
10%	129	114	124	117	119	119	126	120	119	120	128	112
30%	183	149	180	156	182	178	212	183	195	191	220	200
50%	246	209	254	218	244	239	274	248	260	257	294	264
90%	369	365	378	374	372	375	377	370	375	376	382	382
Octane number:												
C.F.R.-M. clear	78.4	79.8	80.2	80.6	78.6	81.0	77.5	80.1	80.4	80.3	74.0	75.5
+3 cc. TEL	86.0	87.9	85.4	87.4	87.3	89.0	83.0	84.3	83.0	83.9	81.9	83.5
C.F.R.-R. clear	87.0	87.6	89.6	91.3	87.1	90.6	88.4	91.6	92.8	93.7	80.9	81.6
+3 cc. TEL	95.3	95.4	96.7	97.5	95.3	97.6	94.2	96.2	95.9	96.5	90.4	92.1

*Tests obtained on raw catalytic motor gasolines after addition of inhibitors.

markedly if the maximum permissible coke were raised above present levels. For example, in the case of the Mid-Continent stock shown in Table 1, an increase in coke from a normal level of 4,500 lb. per hour to 6,500 lb. per hour, based on a 10,000-bbl.-per-day plant, would raise the differential yield of motor gasoline from beads from 410 to 790 bbl. per day. At the same time the butane differential would increase from 310 to 570 bbl. per day and the conversion differential by about 5 per cent. Data for the higher coke level operations on this stock are included in Table 1.

This steeper rate of increase in gasoline production at the deeper cracking levels appears to be characteristic of beads and is of interest because it could be realized with expansion only of the kiln section of the T.C.C. plant. No change is required in the reactor to attain the higher yields, other than an increase in catalyst-bed depth. For example, both types of operation shown above for the Mid-Continent stock could be conducted in the present standard type of T.C.C. reactor, merely by increasing bed depth from 6½ ft. to 18 ft.

The cost of the additional kiln capacity would, of course, have to be balanced against any improvement in over-all refinery position resulting from this change. It is beyond the scope of this paper to evaluate the economics of such a move, the point being mentioned merely because it brings out an added potential advantage of bead catalyst which is not generally recognized and which could not be realized in existing plants simply by changing catalysts. It may, however, be added that higher coke burning capacity is being provided in T.C.C. plants now being designed to handle heavy, liquid feed stocks.[4] Since these plants will also be able to process the present types of distillate stocks, they will be in position to realize the exceptional gasoline increments indicated above if equipped with beads.

Gasoline Quality

Beads show the same tendency toward improved gasoline quality in T.C.C. operations for motor gasoline that characterized their widespread use in wartime aviation operations. This is to be expected since more than half of the total product representing motor gasoline boils in the aviation range. As a rule, motor gasolines from bead cracking possess better octane characteristics, lower sulfur content, lower unsaturation, better gum and oxidation stability, and superior volatility. A comparison of typical motor gasolines from the two types of catalyst is shown in Table 2.

The higher octane rating exhibited by bead gasolines, which on some stocks is as high as two to three points above clay, combined with the higher yield of the bead gasoline, represents an important advantage in terms of over-all octane potential in a refinery. With octane levels already at unprecedented heights and threatening to rise still higher, beads become more and more attractive.

The better sulfur reduction and oxidation stability of bead gasolines can, of course, be translated into reduced finishing costs. The higher volatility, which is essential in imparting quick engine starting, warmup and acceleration characteristics to the gasoline, is an even more important advantage, particularly during winter months, when undercutting is frequently necessary to meet volatility requirements.

For refiners interested in continuing the manufacture of high-octane aviation gasolines the use of bead catalyst offers added flexibility by permitting the production of one or two pass catalytic base stocks higher in quality than can be obtained from clay catalyst. Single-pass operations on beads with suitable stocks can produce full boiling range aviation gasolines with F-3 octane ratings of about 95 and F-4 index values of 110 to 120, with 4.6 cc. TEL. These results are respectively 2 to 5 F-3 octane numbers and 10 to 20 F-4 index numbers higher than from clay. A similar gain will result from two-pass operations from premium quality aviation base stocks, as wartime experience has shown.

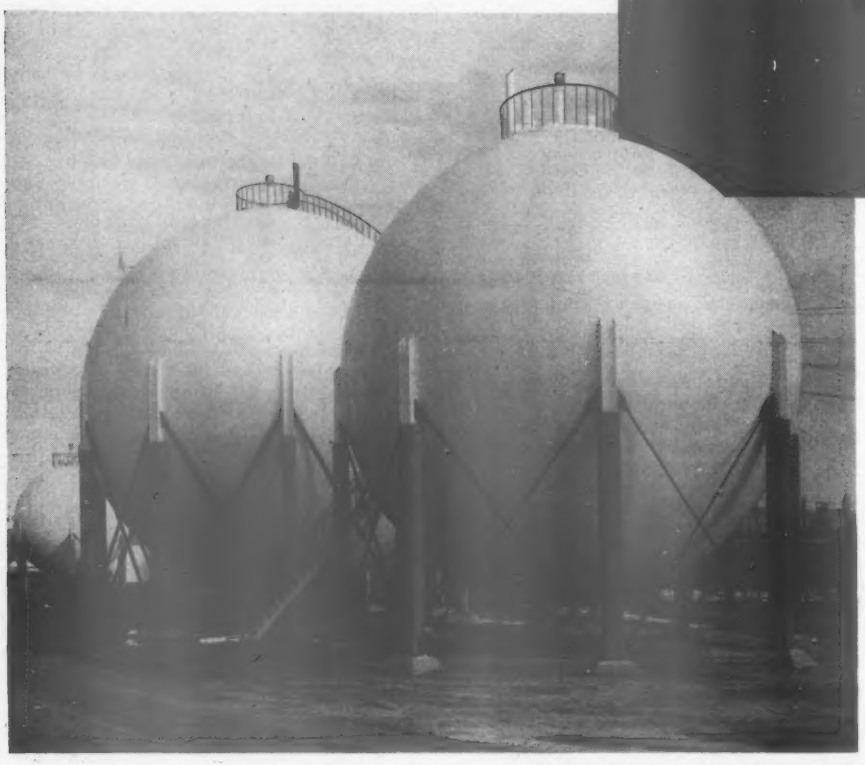
Economic Comparisons

The relative advantage of substituting beads for clay in a given T.C.C. plant becomes more tangible when viewed in terms of economics. While the incremental profit resulting from such a change must be evaluated for each individual refinery case, the results presented below will serve to indicate the order of magnitude of the profit differentials involved. Comparisons are presented on several T.C.C. commercial and pilot-plant operations, including various types of stocks.

For the purposes of this presentation, comparative process earnings for the two catalysts have been developed on the basis of a 10,000-bbl.-per-day T.C.C. plant, translating the production from that plant into total product revenue, and deducting lead and catalyst costs. Other operating costs,

TABLE 3 — PRICES AND QUANTITIES USED IN ECONOMIC COMPARISONS

	Mid-Continent basis	West Coast basis
Price structure:		
10-lb. motor, cents/gal.	5.68	4.75
No. 2 fuel oil, cents/gal.	3.75	2.62
No. 6 fuel oil, cents/gal.	2.37	2.02
Excess butanes, cents/gal.	2.70	3.00
Dry gas, cents/MMB.t.u.	5.00	9.00
TEL, cents/cc.	0.18	0.18
Bead catalyst, $/ton:		
F.o.b. plant	240.00	240.00
Shipping cost	10.60	30.80
Clay catalyst, $/ton:		
F.o.b. plant	80.00	80.00
Shipping cost	11.00	3.20
Blending base stock:		
Bbl. per day	13,000	9,000
Ratio: Thermal to straightrun	50/50	25/75
Clear octane number	58.0	62.5
Octane slope	1.75	1.80
TEL to 78 C.F.R.-M., cc.	1,916,460	839,160
TEL to 78 C.F.R.-M., $	3,450	1,510



Advanced processes in refining require the extensive use of pressure storage tanks and welded steel pressure vessels.

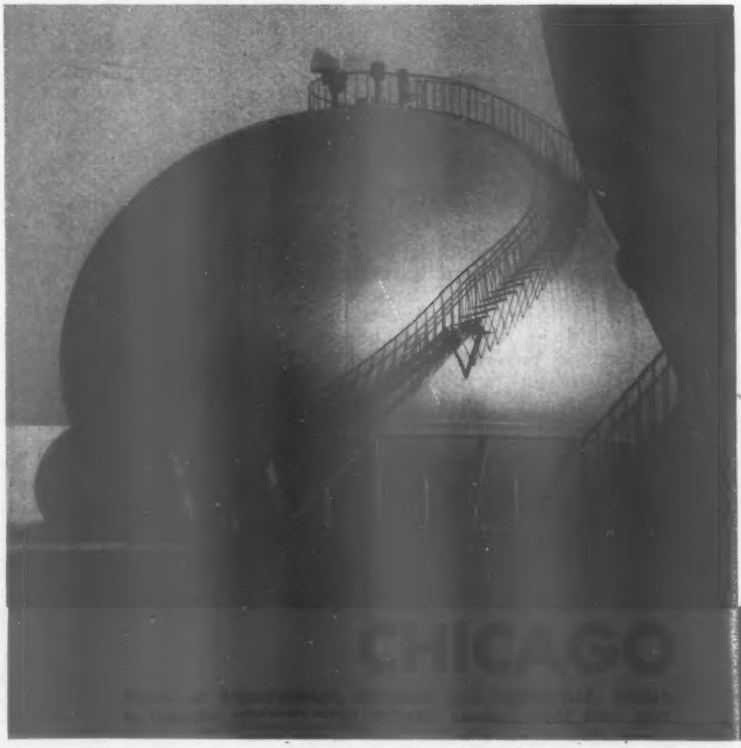
The illustrations on these pages show several typical examples of this type of equipment which we design, fabricate and erect for the petroleum industry.

HORTONSPHERES

The photo above shows three Hortonspheres at a West Coast refinery. The two spheres in the foreground are (left to right) a 12,000-bbl. unit 51 ft. in diam. and a 5,000-bbl. unit 38 ft. in diam. The Hortonsphere in the left background has a capacity of 2,500 bbls. Hortonspheres are used extensively for petroleum products requiring pressures of 25 to 100 lbs. per sq. in. to prevent evaporation loss.

HORTONSPHEROIDS

These large capacity pressure storage tanks are used to store hydrocarbons ranging in volatility from motor gasoline to natural gasoline. They are built in capacities up to 120,000 bbls. The Hortonspheroid shown at the right has a capacity of 15,000 bbls. and is designed for an operating pressure of 25 lbs. per sq. in.



and fixed charges, have been neglected since these are assumed to be approximately the same when operating with either catalyst. The price structure used in determining product revenues is shown in Table 3 and includes values for both the Mid-Continent and West Coast (California) areas.

The lead requirements were based on blending the T.C.C. gasoline with an arbitrary volume of base stock and ethylizing to 78 C.F.R.-M. octane on the total blend. The volume and quality of the base stocks used for the respective cases are also shown in Table 3.

The results of the above calculations are summarized in Tables 4, 5 and 6. Table 4 shows clay-bead comparisons based on pilot-plant operations and Table 5 results based on several representative commercial operations. The commercial-production data have been selected from the most reliable test periods and have been applied without corrections, except for adjustments for vapor pressure and end point of the gasoline and for slight differences in amount of fresh feed charged to the unit.

From the comparisons presented in these tables it will be observed that beads show consistently higher process earnings than clay, the incremental earnings being of the order of $500 to $2,000 per day on a 10,000-

TABLE 4—ECONOMIC COMPARISON OF BEAD AND CLAY CATALYSTS BASED ON PILOT PLANT T.C.C. OPERATIONS

Basis: 10,000 bbl. per day charge and 4,500 lb. per hour coke limit

Charge stock:	Mid-Continent gas oil		Wilmington gas oil	
Gravity, °A.P.I.	28.3		20.8	
Aniline point, °F.	188		132	
Sulfur, % weight	0.41		1.8	
Boiling range, (I.b.p., 50% end point)	522-715-970		533-704-950	
Operating conditions:				
Catalyst:	Clay	Beads	Clay*	Beads
Space velocity, Vol./Hr./Vol.	1.6	1.8	1.8	1.7
Average reactor temp., °F.	886	855	885	880
Octane numbers of 10-lb. motor:				
C.F.R.-M. clear	80.2	80.6	80.2	80.2
+3 cc. TEL	85.4	87.4	82.8	83.8
C.F.R.-R. clear	89.6	91.3	92.6	93.6
+3 cc. TEL	96.7	97.5	95.7	96.4

Products and revenue:	Quantity/ day	$/day	Quantity/ day	$/day	Quantity/ day	$/day	Quantity/ day	$/day
10-lb. motor gasoline, bbl.	3,930	9,375	4,330	10,330	2,500	4,988	3,140	6,264
No. 2 fuel oil, bbl.	3,260	5,135	2,790	4,394	4,615	5,077	4,130	4,543
No. 6 fuel oil, bbl.	2,170	2,153	1,860	1,846	2,485	2,112	2,230	1,896
Excess butanes, bbl.	600	680	1,100	1,248	170	214	370	466
Dry gas, MM B.t.u.	3,620	181	3,905	195	2,437	219	2,990	269
Total		17,524		18,013		12,610		13,438
Catalyst makeup, tons	3.5	319	1.3	326	3.5	291	1.3	352
TEL credit to 78 C.F.R.-M., cc.	649,888	1,170	810,113	1,459	76,020	136	104,933	188
Net revenue		18,375		19,146		12,455		13,274
Differential revenue		.....		771		.....		1,819

*This case is hypothetical since cracking results shown could not be maintained on this abnormal stock without prohibitive catalyst makeup.

TABLE 5—ECONOMIC COMPARISON OF BEAD AND CLAY CATALYSTS, BASED ON ACTUAL COMMERCIAL T.C.C. OPERATIONS

Charge stock:	Paraffinic gas oils		Mixed Base gas oils						Naphthenic gas oils		California gas oils	
Gravity, °A.P.I.	32.2	31.8	33.5	31.9	31.3	34.0	31.2	33.2	28.5	28.7	31.9	31.5
Aniline point, °F.	190	190	170	167	172	162	169	168	148	142	136	137
Boiling range, °F. (I.b.p., 50% e.p.	270-628-760+	502-642-760+	350-635-900	284-616-868	490-595-730	410-615-760+	300-612-760+	470-583-720	390-594-740	420-538-700	377-510-660	381-533-679
Plant	A	B	C	D	B	E	F	B	G	E	H	H & I
Operating conditions:												
Catalyst	Clay	Beads	Clay	Clay	Beads	Beads	Clay	Beads	Clay	Beads	Clay	Beads
Total space velocity, Vol./Hr./Vol.	2.1	0.9	0.7	1.0	0.8	0.7	1.8	0.7	1.8	0.7	1.7	1.7
Recycle space velocity, Vol./Hr./Vol.	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.3	0.0	0.0	0.4	0.5
Average reactor temperature, °F.	935	825	930	950	840	820	910	845	972	830	853	888
Actual total feed, bbl. per day	12,100	11,096	9,100	10,300	9,750	10,500	11,094	9,291	10,800	9,405	9,891	10,775
Actual fresh feed, bbl. per day	12,100	11,096	9,100	10,300	9,750	10,500	6,309	5,742	10,800	9,405	7,733	7,678
Lb./hr. carbon burned	3,067	3,140	3,400	3,770	3,830	2,500	3,800	3,450	3,735	2,425	2,776	2,820
Actual gasoline produced:												
Per cent volume fresh feed	28.8	39.5	39.7	42.1	50.2	39.8	54.0	62.5	35.2	41.8	47.1	49.5
R.v.p., psig.	2.8	6.9	3	5	5	5	2.8	8.0	2.0	5.7	3.0	2.8
A.S.T.M. end point, °F.	418	454	400	430	440	390	460	450	430	380	447	454
C.F.R.-M. clear	76.6	77.8	77.5	76.4	78.6	78.9	76.5	79.6	79.0	82.3	71.4	75.6
Revenue on adjusted fresh feed basis:												
Bbl. per day fresh feed	10,000	10,000	10,000	10,000	10,000	10,000	6,000	6,000	10,000	10,000	7,700	7,700
	$/Day	$/Day	$/Day	$/Day	$/Day	$/Day	$/Day	$/Day	$/Day	$/Day	$/Day	$/Day
10-lb. motor gasoline, 400° e.p.	8,385	8,588	9,471	9,304	11,093	10,520	7,290	7,741	9,781	10,198	6,283	6,959
No. 2 fuel oil	4,961	5,093	4,820	6,109	5,970	6,713	378	791	4,678	4,508	2,653	2,074
No. 6 fuel oil	2,086	2,142	1,523	936	1,214	358	1,857	1,005	1,971	1,899	1,367	1,068
Excess butanes	686	1,032	1,236	930	862	646	644	933	896	1,117	436	990
Dry gas	293	115	195	294	204	299	141	155	259	181	183	406
Total revenue	16,411	16,970	17,245	17,573	19,343	18,536	10,310	10,625	17,585	17,903	10,922	11,497
Catalyst cost	319	326	319	319	326	326	319	326	319	326	291	352
TEL credit to 78 C.F.R.-M.	329	654	987	563	1,275	1,423	173	748	1,317	1,700	—15	377
Net revenue	16,421	17,308	17,913	17,817	20,292	19,633	10,164	11,047	18,583	19,277	10,616	11,522
Average net revenue	16,421	17,308	17,865		19,963		6,714	7,597	15,133	15,827	9,106	10,012
Differential revenue (in favor of beads)		+887			+2,098			+833		+694		+906

TABLE 6—EFFECT OF REACTOR TEMPERATURE ON ECONOMICS OF CRACKING 10,000 BBL. PER DAY MID-CONTINENT GAS OIL OVER BEAD CATALYST
(Basis: Pilot-Plant Operations)

Charge properties:				
Gravity, °A.P.I.		28.3		
Aniline point, °F.		188		
Sulfur, % wt.		0.41		
Boiling range, °F., (I.b.p., 50% e.p.)		522-715-970		
Average reactor temp., °F.	810	830	870	950
Coke deposit, lb./hr.	3,740	4,050	4,700	5,550
Conversion, % vol.	45	50	55	60
Octane No. of 10-lb. motor:				
C.F.R.-M. clear	78.7	79.6	81.7	85.0
+3 cc. TEL	86.2	86.7	87.7	89.3
C.F.R.-R. clear	87.1	88.5	91.4	97.1
+3 cc. TEL	95.4	96.2	97.8	>100

Products:	Quantity/ day	$/day	Quantity/ day	$/day	Quantity/ day	$/day	Quantity/ day	$/day
10-lb. motor, bbl.	4,080	9,733	4,280	10,210	4,350	10,377	4,220	10,067
No. 2 fuel oil, bbl.	3,300	5,198	3,000	4,725	2,700	4,253	2,400	3,780
No. 6 fuel oil, bbl.	2,200	2,183	2,000	1,991	1,800	1,786	1,600	1,593
Excess butanes, bbl.	650	737	920	1,043	1,150	1,304	1,390	1,576
Dry gas, MM B.t.u.	1,796	90	2,725	136	4,211	211	6,508	325
Total		17,941		18,105		17,931		17,341
Catalyst makeup, tons	1.3	326	1.3	326	1.3	326	1.3	326
TEL credit to 78 C.F.R.-M., cc.	496,087	893	631,865	1,138	845,271	1,522	1,164,290	2,096
Net revenue		18,508		18,917		19,127		19,111

bbl.-per-day T.C.C. plant. These earnings are borne out in both the commercial and pilot-plant operations on the various stocks evaluated, and are largely due to higher gasoline, butane, and lead credits for beads. Assuming a differential of roughly $1,000 per day for an average case, the incremental cost of the initial batch of bead catalyst can be written off in less than 3 months.

It will also be noted that the incremental earnings for beads increase appreciably as the octane requirements are raised. Thus, in the case of the Mid-Continent comparison shown in Table 4, an increase in the octane requirement from 78 to 82 raised the incremental earnings for beads from $770 to $990, solely through reduction in lead requirements.

With reference to Table 6, this is included merely to show how process earnings with a given catalyst are affected by variations in the temperature severity of the cracking operation. The results indicate that earnings increase slightly with increase in cracking severity tending to level off in the range of "overcracking." These results are also of interest in connection with the problem of comparing commercial operations wherein differences in severity are frequently encountered.

Abnormal Cracking Stocks

Gas oil charging stocks can be divided into two categories, depending on whether they exert any extraneous effect on catalyst behavior in catalytic operations. One type, the so-called "normal stocks," have no harmful effect, hence are of no immediate concern. These include the usual run of sweet charging stocks, to which the foregoing applies.

The other category comprises the "abnormal" stocks which exert a severe poisoning action on clay catalyst, characterized by marked drop in gasoline yield, increase in gas and coke production and decrease in gas gravity. This effect is entirely different from that exerted by steam and temperature in the normal process of aging described earlier and is so pronounced in the case of some stocks that the activity rating of the clay catalyst drops at the prohibitive rate of one point per cracking-regeneration cycle. On the other hand, bead catalyst is not poisoned by these same stocks, but exhibits virtually normal behavior.

While this phenomenon is not clearly understood, it appears to be associated invariably with stocks of

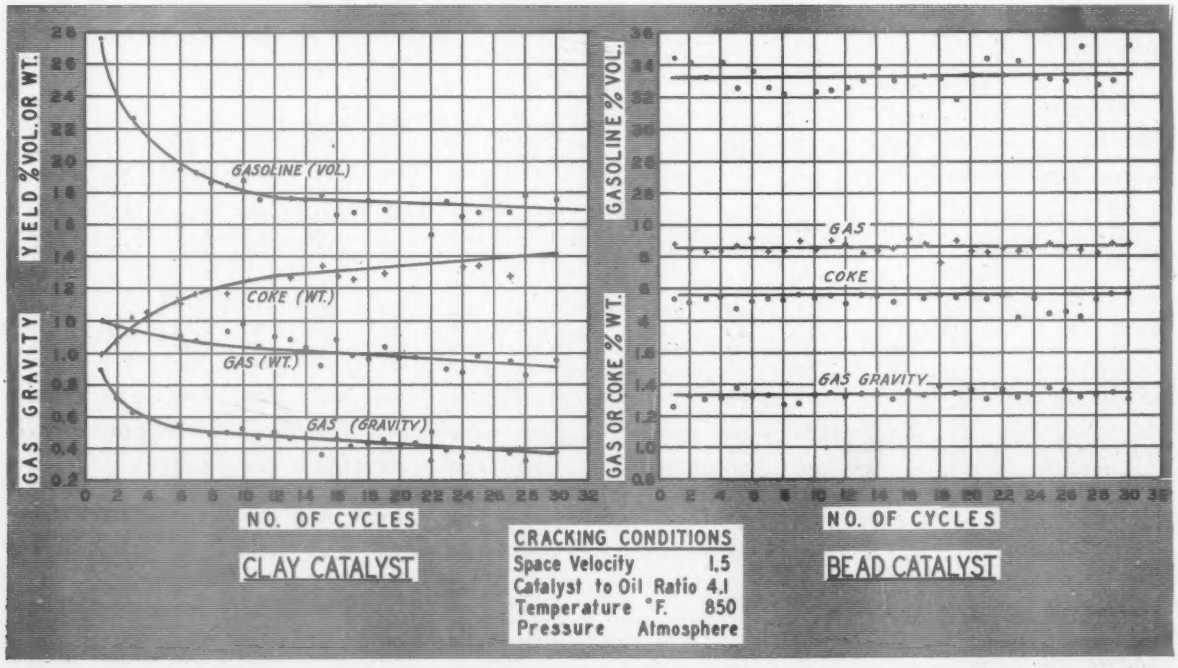


Fig. 3—Comparison of aging behavior of used clay and bead catalysts in cracking heavy Wilmington (California) gas oil. (Special laboratory aging tests)

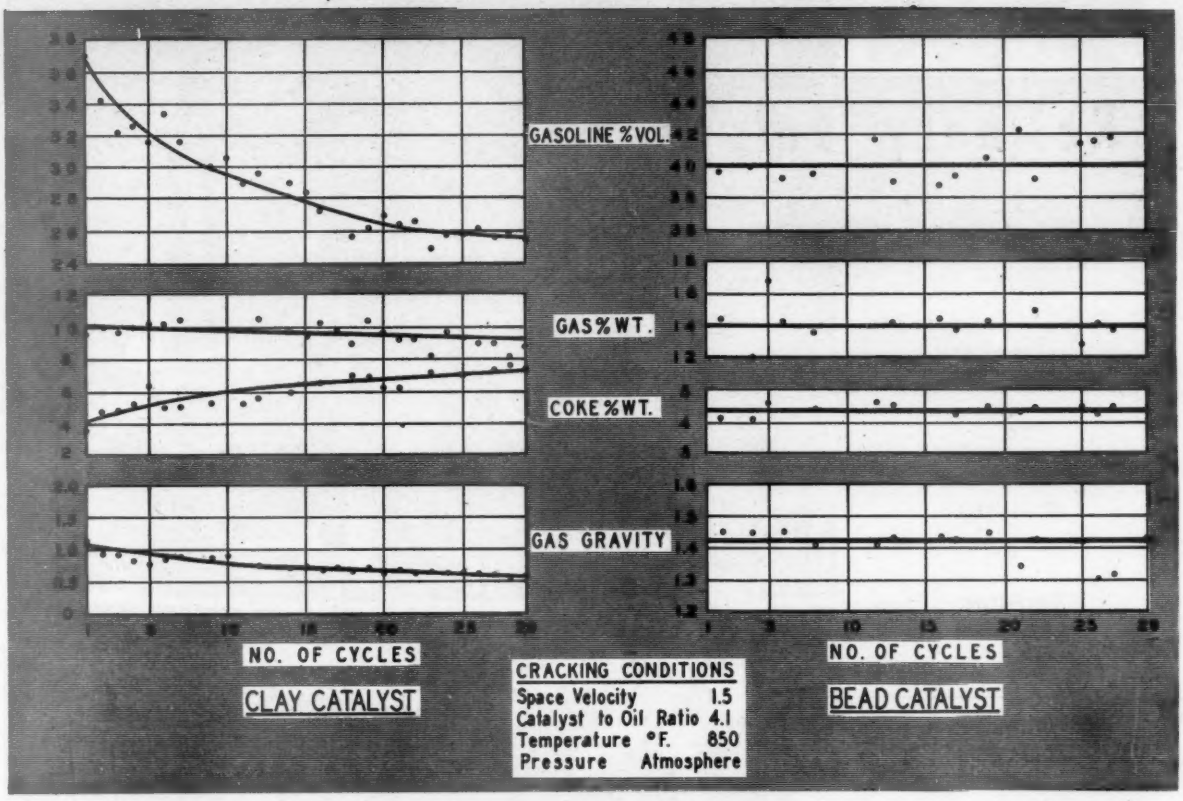


Fig. 4—Comparison of aging behavior of used clay and bead catalysts in cracking West Texas gas oil. (Special laboratory aging tests)

high sulfur content, regardless of crude source, and tends to be aggravated when nitrogen compounds are also present as in many California stocks. In Figs. 3 and 4 are shown laboratory results comparing the aging behavior of used clay and beads toward high sulfur gas oils from two very common domestic crudes, namely, Wilmington (California), and a typical West Texas crude. The laboratory tests comprised 30 cycles of cracking in the static bed under arbitrarily chosen conditions. Properties of the charge stocks are shown in Table 7.

These curves show the striking difference in the relative susceptibility to poisoning of the two catalysts by this general type of stocks. The clay, for example, in both cases shows a drop of 8 to 10 points in gasoline yield in the first 10 cycles with a simultaneous increase of about 40 per cent in coke production, while the beads maintain a perfectly uniform and normal yield pattern over the entire range of 30 cycles. While the rate of aging shown by clay in these tests may not necessarily duplicate that which might be encountered in a commercial unit, it provides ample evidence of this inherent weakness in clay catalyst.

Thus, there are a number of cases where, regardless of other considerations, it would be entirely impractical to operate a T.C.C. plant with clay catalyst. This applies to refineries handling appreciable quantities of high-sulfur crudes and planning to include either the straightrun or thermal gas-oil cuts from these crudes in the charge to the T.C.C. plant. For such cases beads are the answer, and refiners attempting to use clay on these lower grade stocks are undertaking a serious gamble.

In considering the subject of catalytic cracking of "abnormal" stocks more broadly, it may be noted that the abnormality in such stocks is not always confined to the phenomenon of specific poisoning of clay catalyst already described. Certain high sulfur stocks, notably those of California origin exhibit, in addition, a tendency toward abnormally low conversion and gasoline yield when cracked under conditions of normal severity. Moreover, this effect is independent of the type of catalyst used, and is usually associated with stocks of high nitrogen content. The Wilmington gas oil used in the above aging studies is a striking example, being one of the worst stocks of this type encountered to date. By contrast the low nitrogen, high-sulfur stocks, exemplified by West Texas, exhibit normal cracking characteristics, i.e., when cracked over bead catalyst.

An example of the type of results which can be expected from processing the Wilmington gas oil over beads in a commercial T.C.C. unit is shown in Table 4, last column. By way of comparison, data are included for a single cracking cycle on the same gas oil over a normal equilibrium clay catalyst, neglecting for the moment the fact that maintenance of a normal activity level with this stock and catalyst would be impractical.

These results show the low yields and conversion inherent in this stock as compared, for example, with the

TABLE 7

Physical Properties of High Sulfur Wilmington and West Texas Gas Oils Used in Study of Abnormal Aging Effects

Stock—	Heavy Wilmington gas oil	West Texas gas oil
Properties:		
Gravity, °A.P.I.	20.8	30.6
Sulfur, % wt.	1.8	1.8
Nitrogen, % wt.	0.32	Nil
Aniline No., °F.	132	154
Pour point, °F.	25	50
Distillation, °F. (Vac. Assay):		
I.b.p.	533	432
5% vol.	561	476
10% vol.	578	490
20% vol.	589	514
30% vol.	629	538
40% vol.	671	559
50% vol.	704	582
60% vol.	750	606
70% vol.	787	634
80% vol.	826	666
90% vol.	871	706
95% vol.	910	...
End point	*950	740

*Estimated.

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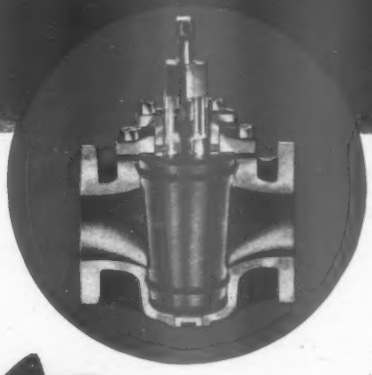

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Mid-Continent gas oil in the same table. Also apparent is the poorer lead susceptibility of the gasoline from the Wilmington stock, although the clear octane rating is remarkably good. The poorer lead response is, of course, due to the higher sulfur content (Table 2) of the gasoline, and reflects the further abnormality of this type of stock that it undergoes less desulfurization on catalytic cracking than West Texas type stocks. The economic comparison of clay versus beads on the Wilmington gas oil, though on an optimistic basis as regards the clay case, confirms the advantage noted on other stocks, for bead catalyst.

In conclusion it must be emphasized that the superior characteristics of the bead catalyst are subject to still further improvement as the result of continuing research and development work on catalysts. For example, in June 1945, changes were instituted in the bead catalyst manufacturing plant at Paulsboro, N. J., which permit marked improvement in sodium content and aging characteristics of the beads. This change alone is expected to raise the equilibrium activity of beads in normal T.C.C. operations by about two to three points, with corresponding improvement in over-all catalyst performance. Current research bears promise of additional improvements which can be realized with no significant change in catalyst cost.

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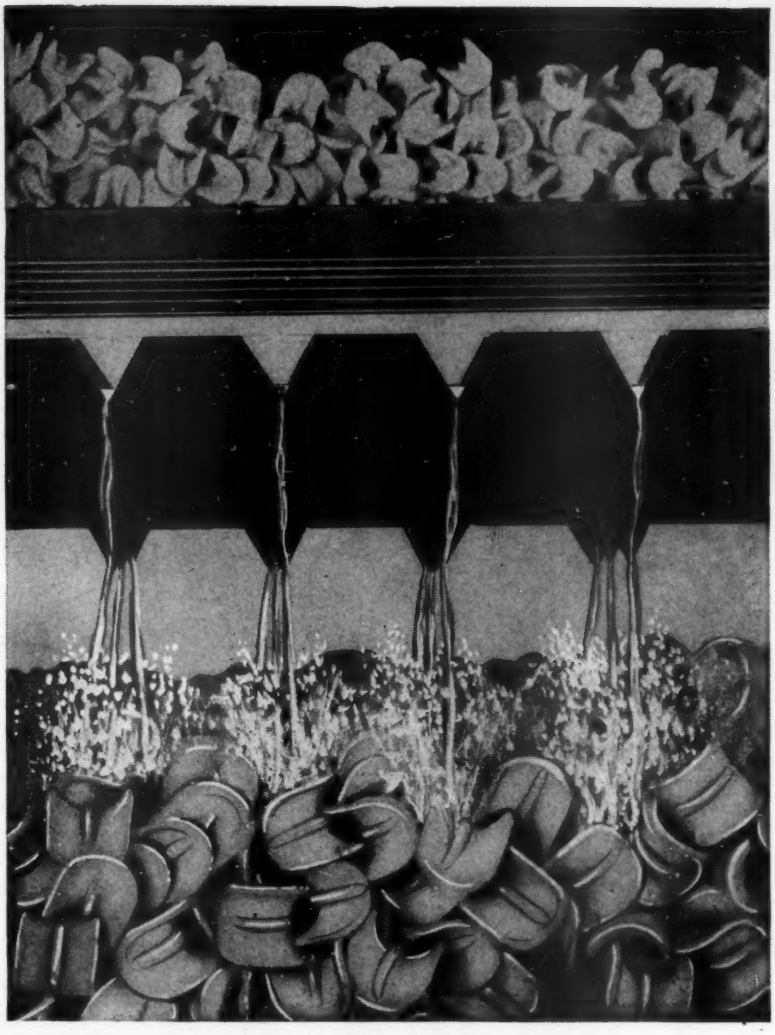
CARTHAGE, Tex. — The new $3,000,000 gasoline plant of United Gas Co. here is now near completion and is expected to be placed in service in the near future.

All processing equipment proper for the 50,000,000 cu. ft.-daily capacity plant is in place, and process piping is 75 per cent complete. Storage facilities, boiler and furnace installations are practically finished. Plant building construction is reported 85 per cent finished. Right of way for the pipe line gathering system being built in connection with the plant has been cleared, and some pipe strung and welded. Gas for the processing will be drawn from the Carthage Pettit lime, from which 215,000 acres of the Carthage pool have been proved for production.



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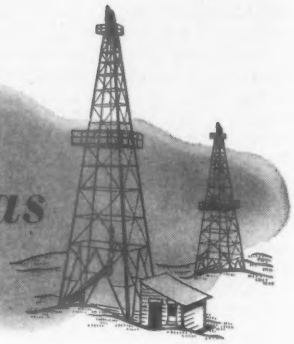

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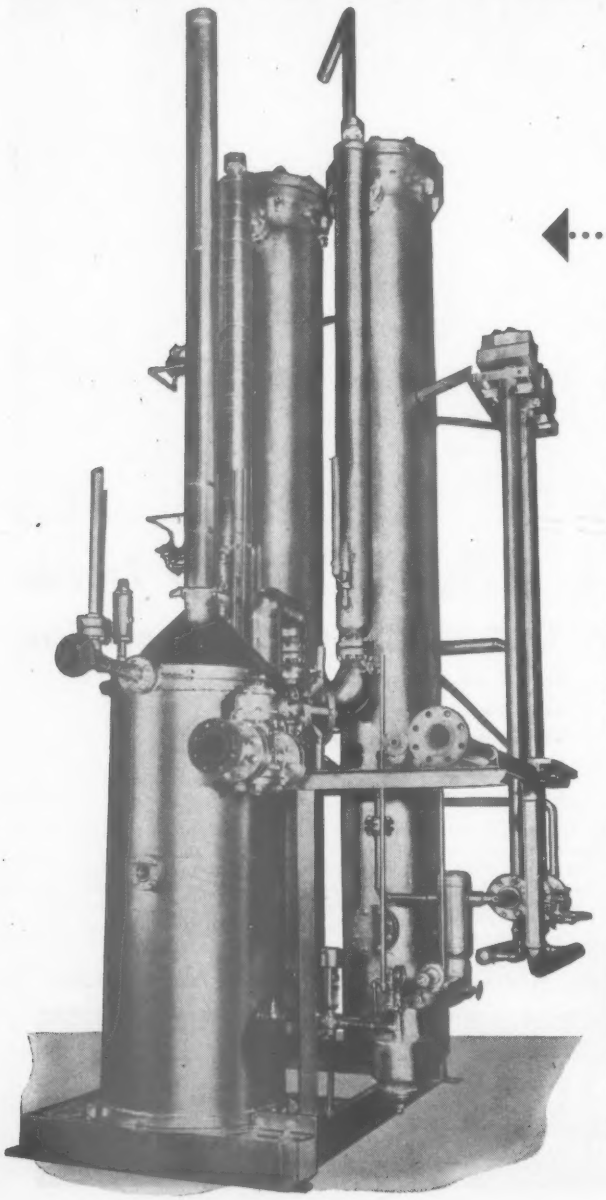

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Propane deasphalting unit embodying the new continuous tower process

Lubricant Stocks Improved By Propane Deasphalting

by J. T. Dickinson and N. R. Adams

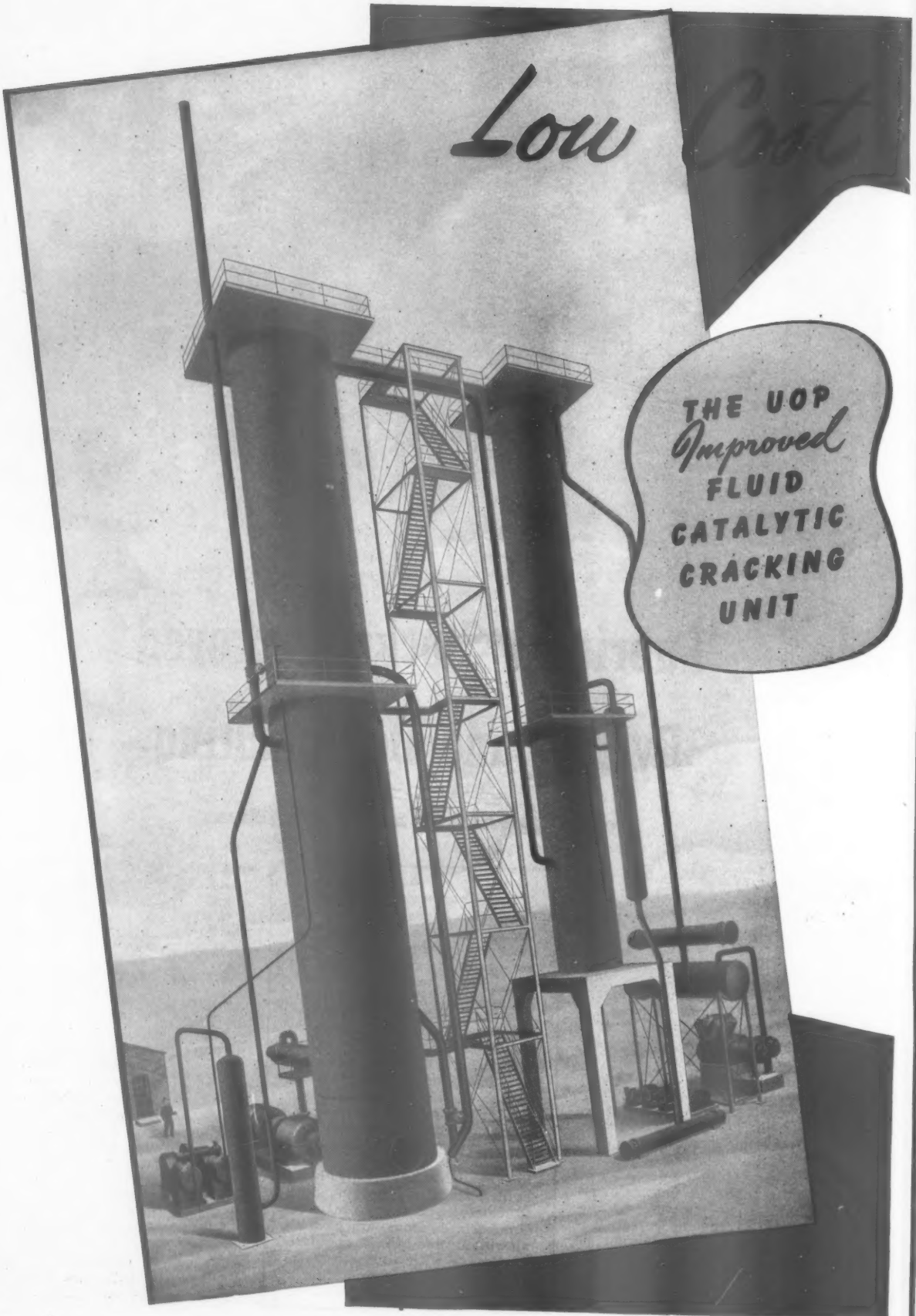
MOST people who are familiar with lube-oil refining are acquainted with the fundamentals of the propane-deasphalting process. It will, however, be worth while to review briefly the basic principles of the process for the benefit of those who may not have thought much about it, since only with some understanding of the process can the present and future possibilities be properly visualized.

It is worthy of mention that propane, the only special material used in the process, can readily be made in most refineries and is available generally in almost unlimited quantities. With the exception of water, propane is probably the lowest cost liquid to be found in any refinery. Either natural-gas propane or so-called refinery propane is satisfactory, and "propane" containing as much as 20 per cent of unsaturates has been used with good results. Propane is regularly shipped by tank cars to all parts of the United States and in smaller containers to other parts of the world. Propane is thus available almost everywhere at a cost which makes the normal operating makeup an unimportant item of operating expense.

THE propane deasphalting process is reviewed from the standpoint of applications and development to date and future potentialities are explored in the fields of both lubricating-oil manufacture and the preparation of catalytic-cracking charging stock. Marked advances in the art are shown to have taken place since the installation of the first commercial propane deasphalting plant in 1934, the most significant being the development of tower deasphalting. Economic potentialities of the propane technique in making available extremely high-boiling gas oils as charging stock to catalytic-cracking units are summarized from an over-all viewpoint and direct comparisons made with alternate methods of feed-stock preparation.

Propane Deasphalting Technique

When reduced crude containing asphalt is mixed with three or more volumes of liquid propane, the temperature at which maximum solubility occurs is usually between 70° and 100° F. If the reduced crude contains high-melting-point asphalt, a portion of the asphalt will not be soluble in the main body of the solution even at 100° and will, with about an equal volume of propane, form a secondary, heavier phase. The fact that the asphalt phase, although truly a solution of asphalt and propane, always contains a low ratio of propane to asphalt is most important, since with a low-ratio asphalt phase and a high-ratio oil phase the difference in the specific gravity of the two phases is always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J. T. DICKINSON

N. R. ADAMS

J. T. Dickinson, in charge of lubricating-oil processing for M. W. Kellogg Co., is a native of Michigan, entering its university in 1915, took time out for World War I as a Naval ensign, graduated from University of Michigan with a B.S. degree in chemical engineering in 1920. He had several years' experience in lubricating-oil manufacture with Standard Oil Co. (Indiana), Sinclair Refining Co., Oliver United Filters, Inc. He has been with Kellogg for a dozen years, in his present field.

Nellson R. Adams started life in Philadelphia, graduated from Pennsylvania State College with a B.S. degree in chemical engineering in 1928, at the age of 20. He took postgraduate work in Massachusetts Institute of Technology and in University of Chicago. He joined the staff of Sinclair Refining Co., eventually becoming a specialist in cost analysis and petroleum economics, and is now director of the yields and economics division of Kellogg.

such as to permit a clean and rapid separation of the two phases of gravity settling.

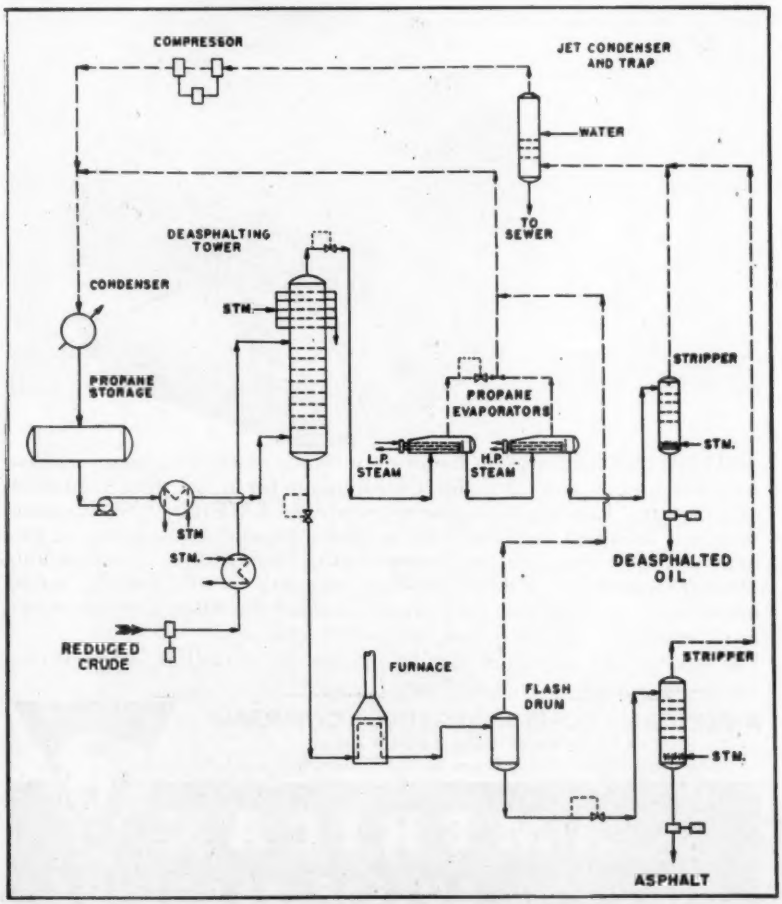
If, after mixing propane and reduced crude at a temperature of 70° to 100° F. the temperature of the solution is lowered, wax (if present in the reduced crude) will separate as a crystalline solid. The propane dewaxing process takes advantage of this fact. The propane deasphalting process is concerned with what occurs in such a solution when its temperature is raised above 100° F., and particularly with the temperature range between 100° F. and the critical temperature of propane, which is 206° F.

The asphalt insoluble in three to eight volumes of propane at a temperature of 100° F. is usually of very high melting point (200°-250° F.). As the temperature of the reduced crude-propane solution is raised about 100° more (lower melting point) asphalt is precipitated, until, at a temperature of 140° to 160° F., the separation of true asphalt is more or less complete. At still higher temperature the lowest gravity and most viscous oil is precipitated, and this phenomenon repeats itself until, as the critical temperature is approached, only a small amount (varying with the character of the reduced crude) of low-viscosity oil remains in solution with the majority of the propane originally added.

It will be obvious from the above that if propane is employed to make a progressive separation of the components of a reduced crude (starting with the portion most readily precipitated) the process may be considered as the reverse of the separation secured by distillation. If the separating sequence secured by distillation be referred to as "topping," then the process of propane deasphalting could properly be termed "bottoming." Distillation starts at one end of the crude and deasphalting at other end. Since the point to which distillation can be carried successfully is limited by the temperature at which cracking occurs (or poor fractionation is secured), the propane process offers the possibility of fractionating a portion of crude oil not previously separated by commercial processes. Recent research indicates that propane fractionation will not only extend the degree to which crude can be fractionated but may also properly replace vacuum distillation over a portion of the range in which the latter process is now being employed.

The first commercial propane deasphalting plant was installed in 1934. Since that time seven additional plants have been installed, making a total of eight now operating. All but one of the plants now operating are used in connection with the manufacture of lubricating oils. The one plant not so used is employed for decarbonizing reduced crude in the preparation of catalytic-cracking feed stock. Although the prime purpose of all existing plants is that of producing a clean deasphalted oil product, the asphalt product from several plants is also utilized as a base material for special asphalt products and road oils. At least one plant produces a variety of exceptionally high-viscosity oils ("resins") for which a ready market has been found.

The lube-oil propane-deasphalting units installed prior to 1940 were all of the so-called "stage" type. In such units the reduced crude and liquid propane are pumped from storage tanks under flow control and the two streams combined, mixed and heated to a predetermined temperature which causes part or all of the asphalt to form a low-ratio phase. The resultant mixture of phases is separated continuously in a settling vessel of special type and a deasphalted oil solution withdrawn from the top of the vessel and an asphalt solution



Typical flow chart of propane deasphalting process—lower type

from the bottom of the vessel. In some such plants provision was made for using a portion of the propane for the purpose of washing the asphalt in order to increase the yield of good oil and to better control the melting point of the asphalt. A few of the stage units have two or more stages of precipitation, with conditions maintained in the primary stage to cause separation of the majority of the asphalt, and conditions in the succeeding stage adjusted to throw out lower-melting-point asphalt or high-viscosity oil. Those plants with more than one stage of separation can produce two or more lower phase products as well as deasphalted oil, if such separate lower phase products are desired.

Three of the existing single-stage deasphalting units have additional equipment which makes it possible to acid treat the deasphalted oil (still in propane solution) and to neutralize the acid oil with caustic or clay after continuous removal of sludge. One operating plant very satisfactorily combines the steps of deasphalting, dewaxing, acid treating, and clay treating (all in propane solution) in such manner that reduced crude is charged and finished bright stock is withdrawn, with asphalt, wax, and sludge as byproducts.

Where stage deasphalting is employed and the oil not subsequently finished by acid treatment, the deasphalted oil is solvent treated. In one such plant the double solvent (Duosol) process is used for solvent extraction. In several other plants the stage deasphalted oil is treated with either phenol or other single solvent. Although the use of a single solvent in such case has the advantage of low solvent-extraction cost in improving viscosity index, it leaves a rather severe decolorizing problem, because the combination of stage deasphalting and single selective solvent is not all that is desired from the standpoint of color improvement and carbon-residue reductions. This situation has been very radically changed by the improvement in propane deasphalting known as the propane tower deasphalting process.

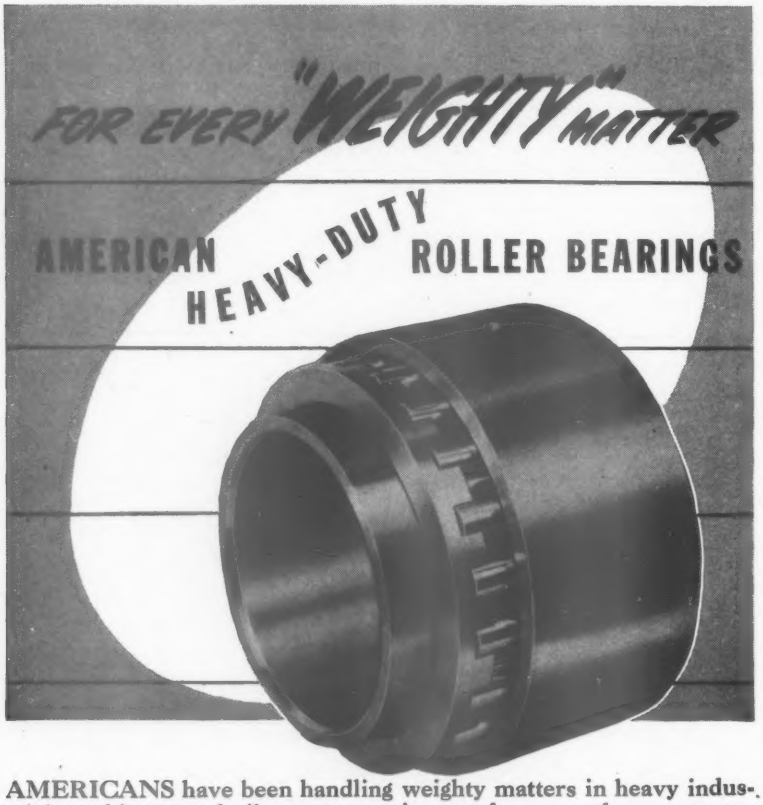
The one propane-deasphalting plant now operating to produce catalytic-cracking charge stock is of the stage type and is designed and operated in a manner very similar to the stage deasphalting units used on lubricating oils. This plant is giving very satisfactory service, but it is likely that all future deasphalting plants installed for making catalytic-cracking charge stock, as well as those for making lube oils will be of the tower type.

Tower Deasphalting in Plant-Scale Units

The tower deasphalting units in commercial use have until recently been employed almost exclusively in connection with the manufacture of aviation lube oil. Several additional tower-type units would undoubtedly have been installed during the past few years if more aviation lube oil had been required or if materials had been available without priority. It now appears likely that a number of new tower units will be installed during the next few years.

In the propane tower deasphalting process a vertical baffled tower takes the place of the settling vessels employed in the stage process. The reduced crude is pumped into the tower at a point roughly midway between top and bottom. The propane is introduced near the bottom of the tower. Deasphalted oil solution is taken off the top and asphalt solution off the bottom of the tower. The temperature of the solution in the different parts of the tower is controlled by regulating the temperature of the reduced crude and propane streams to the tower and by means of steam heat coils within the tower.

To understand what occurs within the tower, consider first the zone between the oil-feed point and the bottom of the tower. Assuming a temperature in this zone which causes precipitation of asphalt, the asphalt phase, being the heavier, starts for the bottom of the tower. As the asphalt phase descends, it is scrubbed by the upcoming stream of fresh pro-



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pane and the more soluble oil which may have started down with the asphalt is dissolved in the propane. With proper selection of the bottom tower temperature the asphalt reaching the bottom is thoroughly freed of good oil and an upflowing oil solution relatively free of asphalt is secured just above the oil feed point. The zone below the oil feed point may conveniently be considered as the lower phase, or asphalt stripping zone.

Although the oil in the propane solution moving upward just above the oil feed point is greatly improved compared with the feed stock, it still contains some asphaltic material which must be removed in order to secure deasphalted oil of good color and low carbon residue. By proper control of the tower top temperature this further improvement is secured in the zone between the oil feed point and the top of the tower. Any material rejected in this zone eventually finds its way to the base of the tower, and only oil thoroughly freed of asphalt is allowed to pass off the top.

Comparing the action of the tower with that of the stage settler, it will be obvious that the settler represents a single stage of separation whereas the tower gives the effect of multistage separation plus countercurrent use of the propane in washing the asphalt phase.

A large amount of pilot-plant data is available showing the results that can be secured by the tower process in preparing reduced crudes of many types for subsequent solvent extraction. The results secured in the first commercial tower installation will serve to show perhaps better than laboratory work what can be expected from reduced crude with above average asphalt content. In this first commercial tower deasphalting plant, which has been operating several years, East Texas reduced crude (15 per cent crude) is charged to the unit and approximately 67 per cent of deasphalted oil and 33 per cent of asphalt by volume produced. The asphalt has a melting point of about 170° F., and the deasphalted oil a color of 6 N.P.A. and a carbon residue of 1.4, with a viscosity of 120-125 S.S.U. at 210° F. After phenol treating to 95 viscosity index and dewaxing to zero pour, the oil has a color (before clay) of 4½-5 N.P.A., a carbon residue of about 0.25, and a viscosity of 120-125 S.S.U. at 210° F. After a light clay treat, the product represents finished aviation lubricating oil.

Advantages of Propane Tower Deasphalting

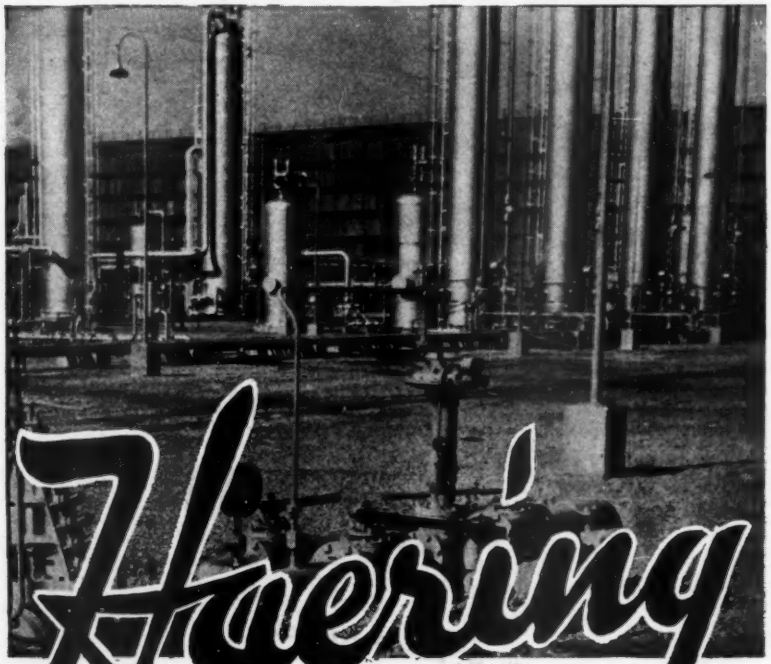
Some of the advantages of the results secured by the tower deasphalting process in the manufacture of lubricating oils from reduced crude may be summarized as follows:

1. The asphalt content is no longer of major importance in considering the value of a reduced crude for the manufacture of lube oils. Deasphalted oil of 5 to 7 N.P.A. color and low carbon residue can be made at low cost whether the asphalt content be 5 per cent or 60 per cent. Almost any crude is now a potential lube crude.

2. Any reduced crude, after being cleaned up by tower deasphalting, can be satisfactorily solvent extracted with a single solvent such as phenol. Tower deasphalting for preparing the reduced crude thus permits the use of a single solvent extraction method for both distillates and bright stock, with resultant advantages in flexibility and low operating cost.

3. When high viscosity index bright stock or aviation lube is made by tower deasphalting followed by phenol extraction, the use of clay for improving color will seldom be required. Bright stock and aviation-lube raffinates of 4 to 7 N.P.A. color can be made from almost any reduced crude by this method of refining. Light clay treating may still be employed to improve such properties as oxidation resistance or demulsibility, but the cost of clay treating can be drastically reduced.

4. The asphaltic material and exceptionally high-viscosity oil from some reduced crudes will be separated with propane into fractions having new and unusual characteristics.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Some products of this sort are already being marketed, and it is evident that their manufacture and sale adds materially to the net return per barrel of crude.

5. In cases where vacuum distillation is being employed or considered for making high-viscosity distillate oils (S.A.E.-30 or heavier), propane fractionation offers the advantage of making cleaner, lighter-colored, lower carbon residue fractions which can be more economically refined to finished products.

Propane Decarbonizing—Cat. Cracker Feed Preparation Aspects

While the preceding discussion of propane deasphalting has been devoted almost exclusively to its application in the manufacture of lubricating oils, there is another application which has recently aroused much interest, namely, the preparation of charging stock for catalytic-cracking units. In this latter role the process is frequently referred to as propane decarbonizing to distinguish it from the more severe separation required in deasphalting for lubricating-oil production. Since there are various known methods of preparing feed stock for catalytic-cracking units it is felt that a brief review of the economic aspects of propane decarbonizing as compared to some of the other feed preparation methods is in order.

During the years of the recent war the problem of preparing charging stock for the large number of catalytic-cracking units which had been erected for aviation gasoline manufacture and other purposes, was not a difficult one. Generally speaking, large volumes of distilled light and medium virgin gas oils as well as visbreaker and coke gas oils were already available. True, the installation of new equipment for this purpose was necessary in some instances but they were definitely in the minority.

Today with the emphasis on the production of motor rather than aviation gasoline the situation is vastly different, particularly for those refiners utilizing or contemplating the use of Fluid catalytic-cracking equipment. In this case actual operations have demonstrated the ability of such equipment to handle more than 50 per cent more fresh feed on motor gasoline operation than on aviation type operations involving severe overcracking of the gasoline product.

Naturally with more potential catalytic-cracking capacity available many refiners are looking for new sources of charging stock with which to fill up their units. What should they do? Should they recycle the first-pass cycle stock or should they look for more profitable alternative charging stock? No specific answer can be given to cover such a broad question but certain related governing principles have already been established. It was earlier mentioned that light and medium gas oils were largely used as "cat cracker" charge during the war. This was fine for that period but the very highest boiling gas oils are today considered the most attractive financially as feed stock for Fluid cracking units. The reason is simple. The low A.P.I. gravity high-boiling gas oils are among the poorest thermal-cracking charge stocks and yet when cracked catalytically they give exceptionally high yields of high octane motor gasoline.

Very naturally refiners with Fluid cracking units available as well as those contemplating erection of such equipment are vitally interested in the subject of feed stock preparation. What then are the various methods of preparing charging stock which must be taken into consideration? The following list is believed to cover the important ones:

Case 1—Vacuum flashing.

Case 2—Delayed coking.

Case 3—Propane decarbonizing.

Case 4—Viscosity breaking.

Case 5—No preparation (direct fluid catalytic cracking of reduced crude).

While all of these processes should be taken into account by anyone giving serious consideration to an installation problem, it was felt advisable in the present instance to limit the scope of the discussion to the first three.

There are obviously many ways in which it might be possible to compare the relative economic merits of

three different methods of feed stock preparation. The one chosen for the present purpose, however, was to select a fixed quantity of crude, assume the erection of all new process equipment in a completely integrated refinery in all cases and then make an over-all economic balance covering each of the individual cases. The assumption that no existing equipment could be used in setting up feed-preparation units is arbitrary but felt to be justified in a general study of the present nature.

The actual basis selected was 40,000 bbl. per calendar day of a 38° A.P.I. paraffinic crude—its character roughly similar to those of Mid-Continent origin. In all three cases it was assumed that atmospheric topping would be carried out to 30 per cent bottoms on crude followed by cat-cracker feed stock preparation on the reduced crude. Catalytic cracking to a high conversion level by recycling, thermal reforming of virgin heavy naphtha as well as catalytic polymerization of propylenes and butylenes were common to all cases. Thermal reforming of coker gasoline was used under Case 2 in order that the over-all comparison be made on the basis of gasolines of constant quality. Every effort was made to maintain strict comparability in setting up the comparison.

Greater Yields of High Octane Gasoline From Crude

In order to present the results of the study with a maximum of simplicity it was felt advisable to break down the composite picture into its essential component parts. In order of their chronological establishment the summarization given in Table 1 presents over-all refinery-yield data for the three cases considered.

It will be noted from this tabulation that vacuum flashing results in the lowest gasoline yield of the three cases, while propane decarbonizing gives the highest gasoline yields of all. The yield advantage for propane decarbonizing over delayed coking is not very large, however.

In order to establish an over-all economic comparison between the several cases it was necessary to fix a price structure for some specific petroleum refining area. The tabulation presented in Table 2 was assumed to be typical for the Chicago area.

Over-all Economic Position of Propane Decarbonizing

Using the price structure given in Table 2, over-all refinery operating costs were calculated and a determination made of the net credits accruing to each of the cases. Table 3 presents a summarization of the net incremental earnings of Cases 2 and 3 over those of the vacuum distillation case (Case 1) together with a summarization of the net incremental process investment requirements. Offsite facilities would be approximately the same for all cases.

A brief study of Table 3 indicates that for the particular set of conditions assumed, delayed coking and propane decarbonizing are highly competitive and both are financially more attractive than vacuum distillation as a method of preparing "cat cracker" charging stock. It should be pointed out that this comparison is made on the basis of over-all blended fuel oils of varying viscosity. The actual fuel-oil viscosities for the three cases were calculated to be as follows:

	Vis. S.S.F. at 122° F.
Case 1 (vacuum)	850
Case 2 (coking)	20
Case 3 (propane)	400

While at first glance the above basis of comparison might not appear to be fair, nevertheless in many refineries it is quite possible to burn some of the very heavy fuel-oil components directly in the plant or even sell them as asphalt. In such cases the comparison is felt to be fair as it stands. To cover another situation, however, an over-all economic comparison was made blending all fuel oils to a maximum viscosity of 125 S.S.F. at 122° F. using light catalytic cycle oil as the cutting stock. Table 4

TABLE 1—YIELDS

Yields, vol. % on crude:	Case 1 Vacuum dist.	Case 2 Delayed coking	Case 3 Propane decarbonizing
Regular gasoline—80 C.F.R.-M.	47.6	49.1	49.8
Premium gasoline—85 C.F.R.-M.	11.8	12.2	12.5
Total gasoline	59.4	61.3	62.3
Kerosene	12.0	12.0	12.0
Furnace oil	9.7	10.0	10.1
Fuel oil	11.4	3.7	8.2
Gas (fuel oil equivalent)	7.1	10.2	7.3
Coke (recoverable)	...	*5.4	...

*Weight per cent.

TABLE 2—PRICE STRUCTURE—CHICAGO AREA

	Unit price
Regular gasoline—80 C.F.R.-M., per gal.	$0.0650
Premium gasoline—85 C.F.R.-M., per gal.	0.0725
Kerosene, per gal.	0.0500
Furnace oil, per gal.	0.0450
Fuel oil, per bbl.	1.15
Gas (fuel oil equivalent), per bbl.	1.15
Coke (recoverable), per ton	6.00

TABLE 3—ECONOMIC COMPARISON—CHICAGO AREA

	Case 1 Vacuum dist.	Case 2 Delayed coking	Case 3 Propane decarbonizing
Incremental credits over Case 1, ($/year)	.....	$516,000	$558,000
Incremental investment over Case 1 (processing equipment)	.....	610,000	470,000

TABLE 4—ECONOMIC COMPARISON OF INCREMENTAL INCOME AND INVESTMENT OVER VACUUM FLASHING AFTER ADJUSTMENT TO MAXIMUM FUEL-OIL VISCOSITY AT 125 S.S.F. AT 122° F.—CHICAGO AREA

	Case 1 Vacuum dist.	Case 2 Delayed coking	Case 3 Propane decarbonizing
Incremental credits over Case 1 ($/year)	.....	$823,000	$720,000
Incremental investment over Case 1 (processing equipment)	.....	610,000	470,000
Previous annual credit over Case 1 (varying viscosity basis)	.....	516,000	558,000

TABLE 5—PRICE STRUCTURES—GULF COAST AND EASTERN SEABOARD

	Gulf Coast unit price	Eastern seaboard unit price
Regular gasoline—80 C.F.R.-M., per gal.	$0.0575	$0.0750
Premium gasoline—85 C.F.R.-M., per gal.	0.0650	0.0825
Kerosene, per gal.	0.0413	0.0560
Furnace oil, per gal.	0.0375	0.0520
Fuel oil, per bbl.	0.97	1.51
Gas (fuel-oil equivalent), per bbl.	0.54	1.51
Coke (recoverable), per ton	1.50	6.00

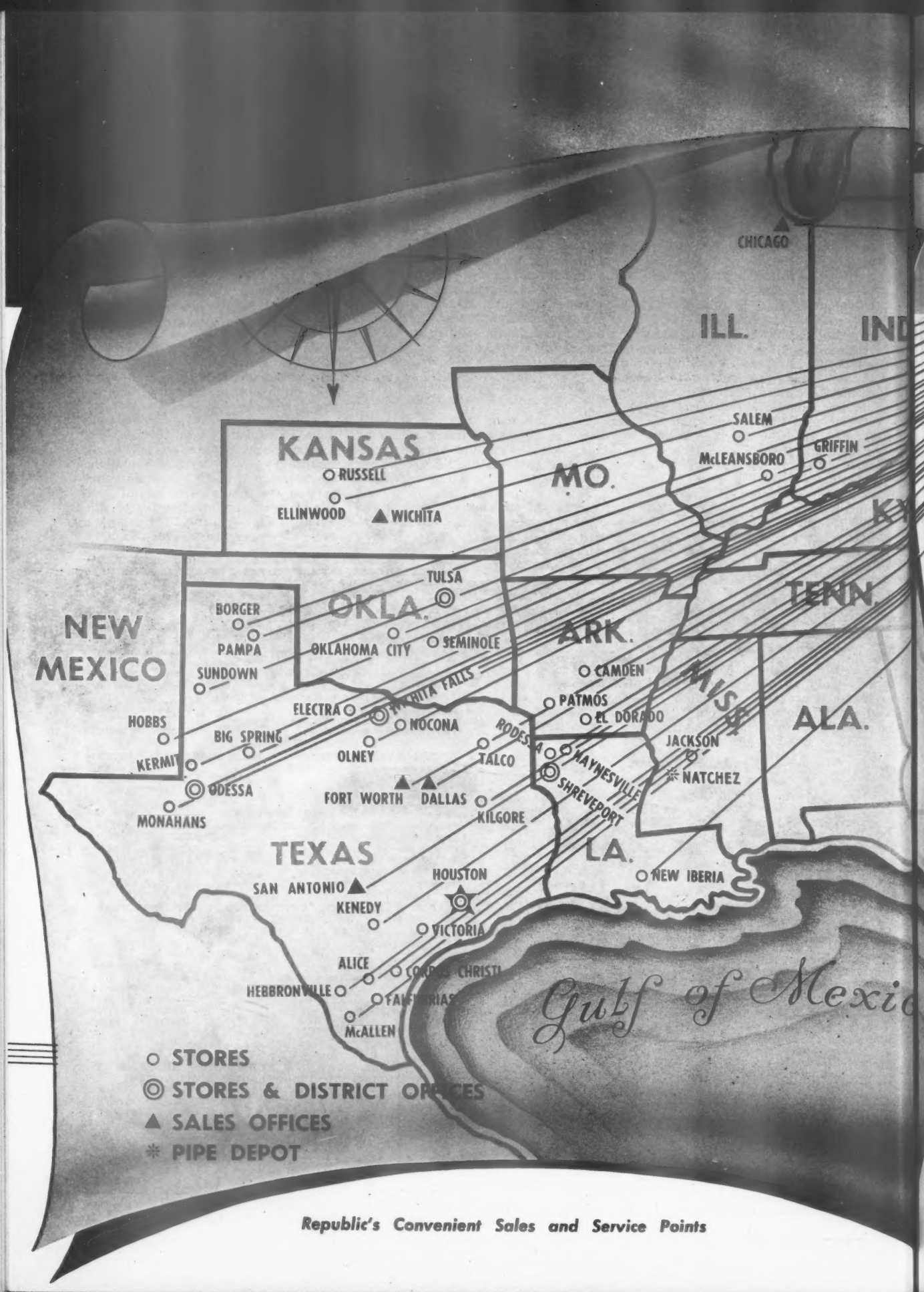
TABLE 6—ECONOMIC COMPARISON IN INCREMENTAL INCOME OVER VACUUM FLASHING AS A FUNCTION OF PRICE STRUCTURE*

Incremental credits over Case 1 ($/year):	Case 1 Vacuum dist.	Case 2 Delayed coking	Case 3 Propane decarbonizing
Chicago area	.....	$516,000	$558,000
Gulf Coast	.....	—63,000	560,000
Eastern seaboard	.....	407,000	640,000

*Basis varying fuel-oil viscosity.

TABLE 7—BREAKDOWN OF INCREMENTAL INVESTMENT REQUIREMENTS OVER VACUUM DISTILLATION

	Case 1 Vacuum dist.	Case 2 Delayed coking	Case 3 Propane decarbonizing
Delayed coking	.....	$800,000	.....
Propane decarbonizing	.....	.....	$50,000
Fluid catalytic cracking	.....	—480,000	370,000
Miscellaneous	.....	290,000	50,000
Total	.....	$610,000	$470,000



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presents the revised economic summary showing the effect of this change on the over-all picture.

It will be noted that vacuum distillation suffers the worst from the new condition imposed from a differential standpoint while coking improves its position relative to propane decarbonizing due to the initially low fuel-oil viscosity for Case 2.

Price Structure a Major Factor

In as much as marketing conditions and price structure are known to be very important economic factors in a study of this nature it was decided to translate the over-all picture to Gulf Coast and eastern seaboard locations to note the effect on the various cases. To do this it was necessary to assume price structures for these areas. These are presented in Table 5.

Since consideration is being given only to the relative economic merits of the three feed stock preparation methods under consideration, it was felt unnecessary to try to compare over-all net credits as from the various areas. However, Table 6 does present an over-all summarization of the relative merits of the various cases for the three refining districts covered.

It will be noted that when shifting over from the Chicago area to the Gulf Coast the low value for coke and the availability of cheap natural gas for fuel result in a reversal of the positions of vacuum distillation and coking. Propane decarbonizing, however, maintains a commanding economic lead over either process. Figures developed for the eastern seaboard are not essentially different than those presented for the Chicago area except that they reflect generally higher differentials as between the various cases due to a basically higher price structure.

One rather interesting phase of this study which has not yet been covered relates to the breakdown of incremental investment over the vacuum distillation case for the various pieces of process equipment involved. It was indicated originally that the size of the Fluid catalytic-cracking unit and other pieces of process equipment were allowed to vary in accordance with the amount of feed stock made available in the several cases. Table 7 presents a summation of such incremental investment figures using Case 1 (vacuum distillation) as a basis.

It has been observed that while investment requirements for feed preparation equipment alone are of significant importance, that the differential investment requirements for catalytic-cracking equipment are also vital to the analysis. It might be noted, for example, that the Fluid cracking unit for Case 3 (propane decarbonizing) is considerably larger and more expensive than that required under Case 2 (delayed coking). This investment differential practically offsets the increased cost of the coker over the propane decarbonizing equipment, resulting in a rather small over-all net investment differential as between the two cases.

Future Potentialities

The authors do not make so bold as to try to draw any rigid over-all conclusions from the economic figures developed in this article. Rather they hope to point out to various interested parties some of the factors involved, the magnitude of their importance and the complexity of the problem itself. Local conditions and availability of existing equipment frequently turn out to be dominant factors in actual individual studies, whereas they have presently been ignored for the sake of simplicity. Generally speaking, it is observed, however, that propane decarbonizing and delayed coking appear to be highly competitive processes both in the Chicago area and along the eastern seaboard while both processes have an economic advantage over vacuum flashing in these areas. On the Gulf Coast, however, where there is little or no market for coke, vacuum flashing shows an economic advantage over delayed coking. Propane deasphalting maintains its advantage over vacuum flashing in this area due primarily to the ability of the process to deliver a larger amount of heavy gas oil to the catalytic-cracking unit.

While an effort has been made to analyze the problem of catalytic-cracking feed preparation in terms of three refining districts, actually the price structure rather than the area is the important factor. Thus the general principles developed may be applied to almost any area. One word of caution is suggested in interpreting this analysis, namely, that it was based entirely on a specific type of crude oil. The relative position of the various feed preparation methods would be expected to be quite different on crude oils of a radically different nature; for example, on those containing widely different qualities of asphalt and made up of gas-oil components of an entirely different chemical structure. Also the present study is predicated on a crude oil of moderate sulfur content whereas additional advantage would accrue to the propane decarbonizing case had a high sulfur crude been considered. This is due to the small amount of corrosion protection required to handle high-sulfur charging stocks in modern propane-decarbonizing equipment.

Colombian Refinery Planned

BOGOTA.—A refinery with a capacity of more than 40,000 bbl. a day will be built by Compania de Petroleo Shell de Colombia at Gaita, Municipio de Santa Marta, according to reports current here.

This cycling plant, recently completed, is one of many gas processing units designed and constructed by Petroleum Engineering, Inc. in the past 16 years of continuous service to the industry. *Petroleum Engineering, Inc., Offices: Houston and Tulsa.*

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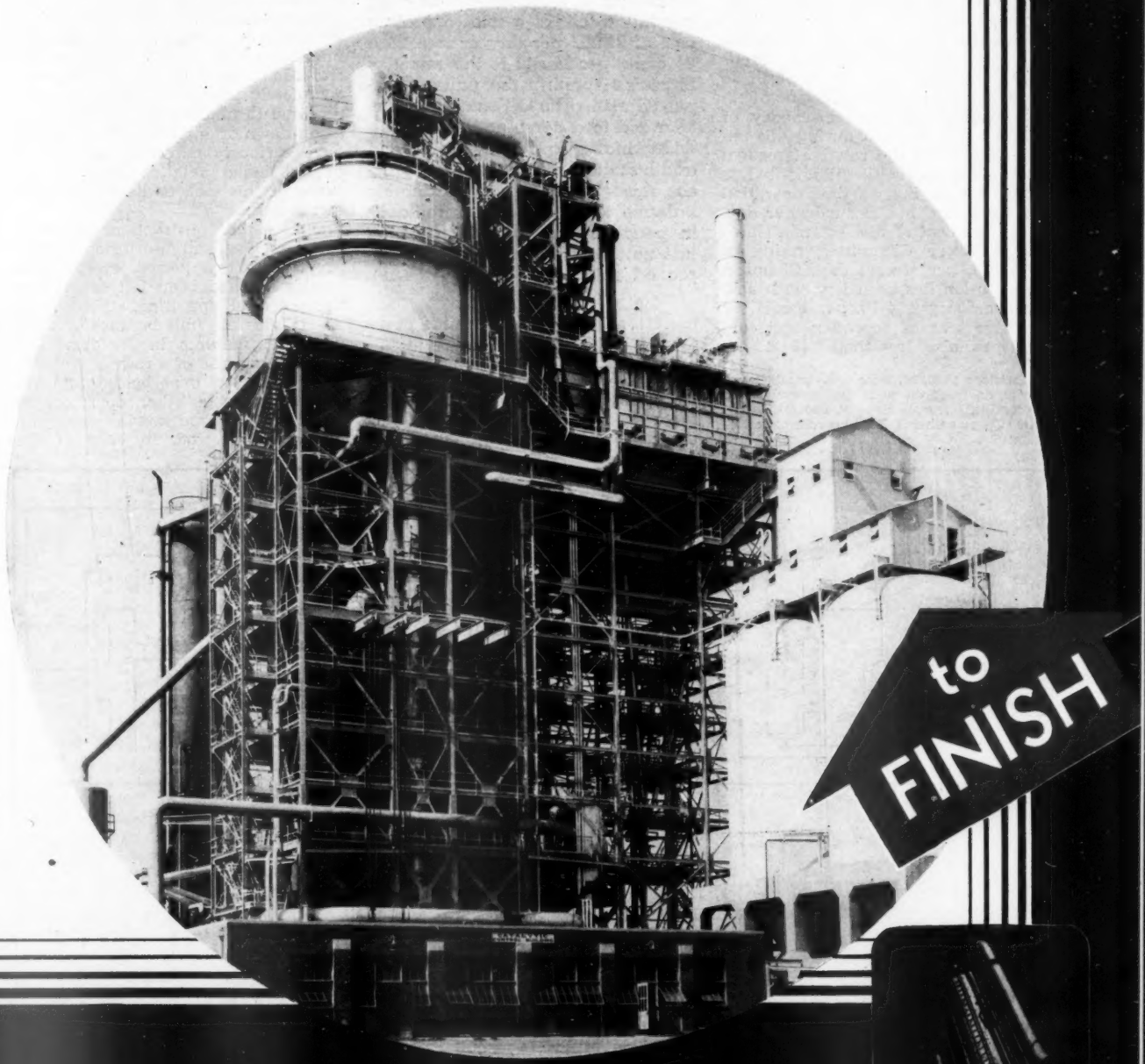

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Economic and Successful Operation Obtained at HF Alkylation Plant

by John A. Scott* and Robert M. Cooper†

Operating a 2,000-bbl.-per-day HF alkylation unit at a total operating cost of $1,607 per day or less than 81 cents per barrel is the result of Sinclair's running the unit at Corpus Christi. The HF stripper was changed to a combination stripper-defluorinator to reduce both acid and bauxite consumption. The process must prove a good economic balance to be operable profitably in peacetime, a conclusion which has not been either proved or disproved yet.

AFTER a period of 20 months of almost continuous operation at high production rates, the HF alkylation unit at Sinclair Refining Co.'s Corpus Christi refinery has proved itself to be an economical and efficient plant. The average onstream efficiency of 95.5 per cent realized during this period speaks for the relative freedom from operating difficulties. Alkylate production during wartime operation averaged 1,996 bbl. per calendar day, or 119 per cent of the Aviation Gasoline Advisory Committee rating of 1,675 bbl. per stream day. Chemical consumption has been low, with acid use averaging 0.84 lb. per barrel for the first year of operation and currently running less than 0.40 lb. per barrel on lower-rate peacetime operation.

*Assistant to E. W. Isom, vice president in charge of research and development, and †Operating foreman Houdry and alkylation units, Corpus Christi Refinery, Sinclair Refining Co.

The refinery may be termed a streamlined 100-octane plant built practically from the ground up during the war period to augment the nation's production of 100-octane gasoline. Due to wartime demands on fabricated steel, it was necessary to limit hydrocarbon storage to a bare minimum. Because of this circumstance, and also the fact that the refinery was completely integrated, all units were required to function on schedule, and a shutdown of any one of them would have seriously curtailed the output of 100-octane aviation gasoline because of this lack of light hydrocarbon storage.

During the construction period in 1943 and 1944, and also for some time previous to that period, considerable trepidation had been felt concerning the potential operating efficiency of an HF alkylate unit because of some uncertain features in its operation, and also because of a rash of troubles that had been experienced and reported by some other operators of units of this type coming onstream during this period. In view of the

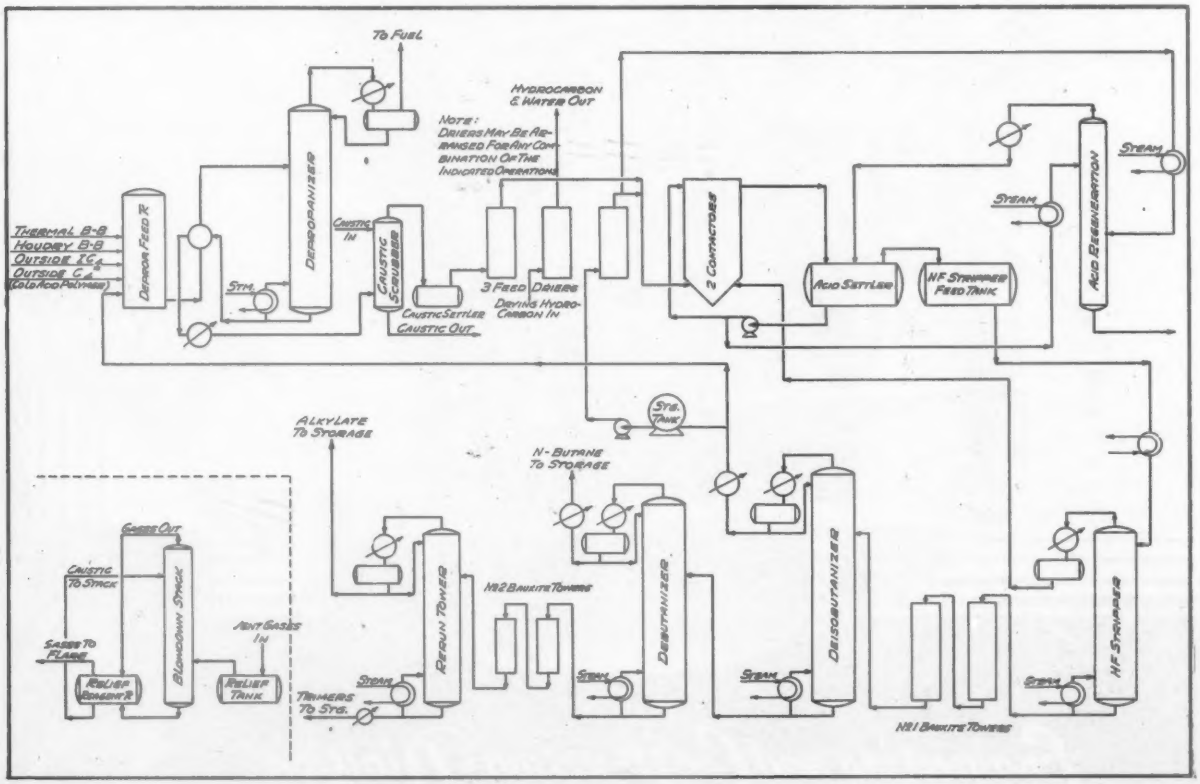

Fig. 1—War-period flow diagram of Sinclair's HF alkylation plant

potential serious effect of a shutdown of the alkylation plant on the operation of the refinery as a whole, every effort was made to insure reliable operation of this unit.

A considerable amount of pilot-plant work had been done during 1941 through 1943 in Sinclair's research and development laboratories thoroughly to explore all probable operational problems and remove bugs existent in the process, and this background plus the early experiences of other commercial operators was used to maximum advantage. As a result of the knowledge accumulated, and also because of the rapidly expanding requirements for 100-octane gasoline during this period, some last-minute design changes were made, and also many minor changes were incorporated later in the field. Among the important last-minute major design changes made were: (1) Increase in fractionating-tower capacities to enable complete utilization of isobutane and olefins, including amylenes, and (2) efficient depropanization of all feed stocks entering the alkylation section. This last change was made to eliminate the necessity for venting the HF stripper feed tank and thus conserve on HF, which at that time was in short supply. Complete success was realized in this respect and at no time has it been necessary to vent this drum with the consequently obvious beneficial effect on acid consumption. Changes made in other fractionating equipment and certain auxiliaries permitted productions up to 2,500 bbl. per day, as compared to the original design of 1,200 bbl. per day.

Changes and Innovations

In addition to the design changes permitting high production rates and conservation of acid, many changes and innovations were made to insure trouble-free and continuous operation of the unit. Among these were:

1. Conversion of the HF stripper to a combined stripper - defluorinator. This change was made to conserve acid and bauxite defluorination catalyst. Features of this installation are: (a) Use of active copper-bearing aluminum rings; (b) installation of a 5-ft. bed of steel rings at the top as a guard against acid corrosion of the aluminum rings; (c) installation of an oversized preheater to enable obtaining a 200° F. preheat so as to flash off most of the dissolved HF in the guard section; (d) installation of an orifice bypass around the stripper overhead release valve to insure a minimum net overhead of 10 per cent on feed to take care of upsets in the tower and possible closure of this control valve. This device furnished further assurance against acid contact with the aluminum rings and also acid contamination of the bauxite chambers following the stripper.

2. Installation of a simplified single-tower acid-regeneration system with complete elimination of all acid-regeneration pumps, controls, and other unnecessary equipment.

3. Installation of manifolding at the feed dryers to permit drying of all hydrocarbon streams entering the contactors, including recycle isobutane, and thus minimize acid loss in the regeneration unit.

4. Installation of magnetic float gage tubes of simple design on the contactors to permit frequent and reliable checks on acid: hydrocarbon ratios.

5. Installation of magnetic float gage tubes on all acid vessels permitting reliable, safe, and trouble-free determination of acid levels at all times.

6. Based on pilot-plant experience, the widely adopted practice by others of welding all HF service threaded pipe connection was discarded to permit flexibility of maintenance. Complete success was obtained with these unwelded joints.

7. Disassembly of all valves, including check valves, to insure that no asbestos-filled gaskets or packing had been erroneously supplied by equipment manufacturers. This search was well rewarded as several asbestos gaskets were found which would have resulted in early and possibly frequent emergency shutdowns.

8. Installation of gas-oil seal pots in all acid-service control instruments to protect meter bodies from acid contact.

9. Use of special ½-in. drilled barstock nipples on all acid-sample and pressure-tap connections as a safety measure.

In addition to these design and construction items, several features of operating technique contributed to trouble-free performance. Among the most important of these were:

1. Thorough training of operators and the use of men experienced with HF technique, obtained in pilot-plant work, for assistants in the early operation.

2. Continuous operation of duplicate contactor seal oil pumps to insure against failure of the vulnerable contactor seals. This practice prevented more than one otherwise unavoidable shutdown.

3. Systematic and thorough servicing of acid-service valves.

4. Use of magnesium oxide plasters on small acid leaks to prevent them from growing and thus cause shutdowns, and also to maintain an acid-free atmosphere. In many cases this practice resulted in self-sealing of small leaks.

5. Watchful check on pump gland and valve gland flushing oil pressure at all times.

The performance of the HF stripper has contributed much to the eco-

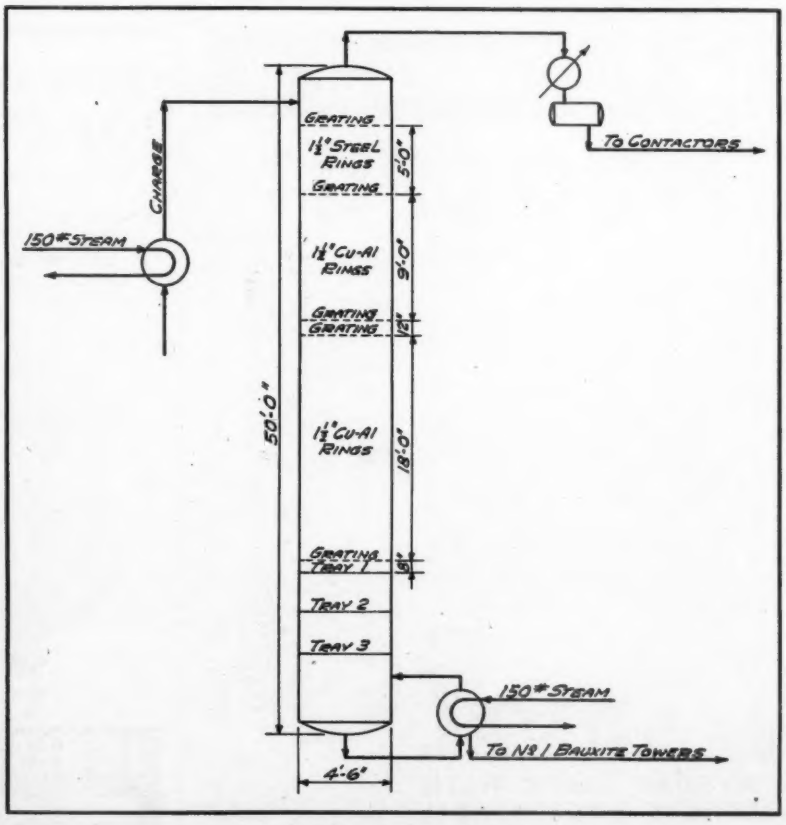

Fig. 2—Details of defluorinating stripper

from rig to refinery

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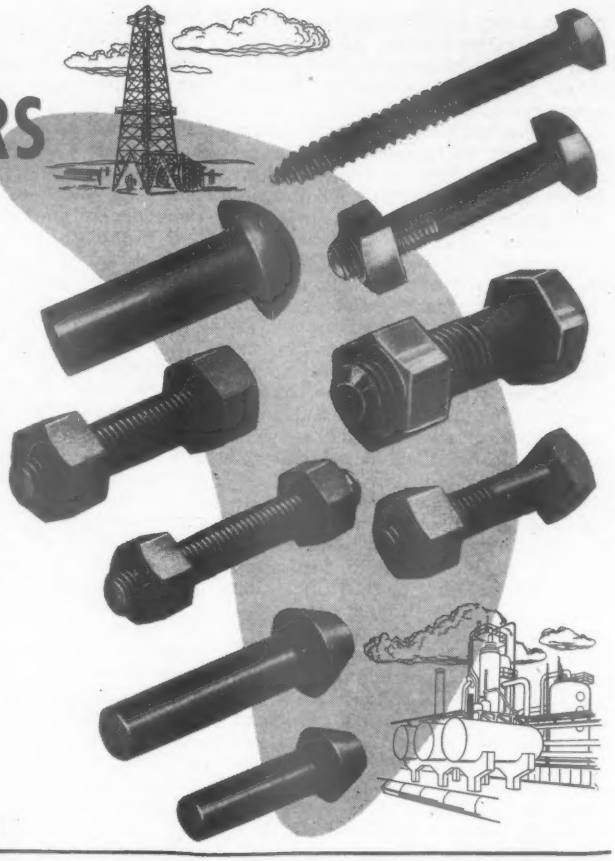

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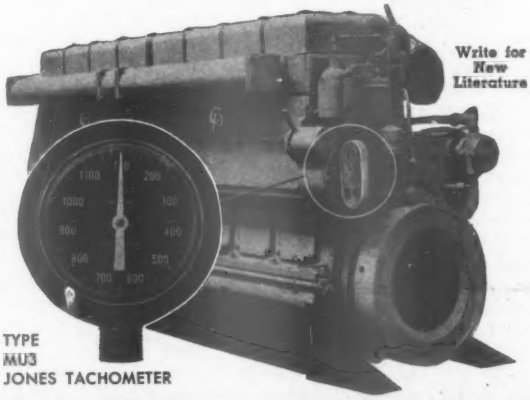

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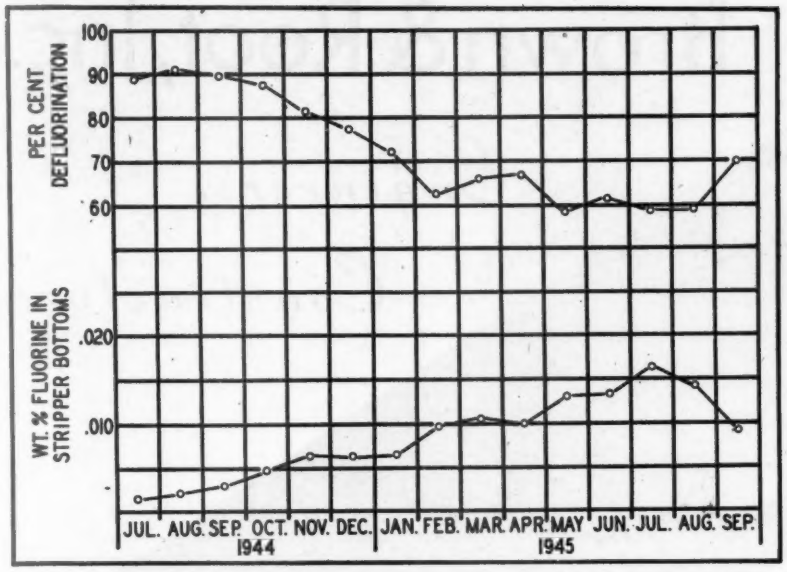

Fig. 3—Weight per cent of fluorine remaining in alkylate stripper bottoms (lower), and per cent of total fluorine removed in the defluorination step (upper)

nomical and trouble-free operation. Fig. 2 shows the general features of the vessel. The tower was designed for and operated at 300 lb. so that higher temperatures and consequently better defluorination could be obtained than with lower pressures. Copper-bearing aluminum rings make up an 18-ft. bed in the lower part of the tower. The upper bed consists of 9 ft. of copper-bearing aluminum rings topped by 5 ft. of steel rings. In operation the charge to this tower is maintained in the range of 200° to 220° F. which temperatures serves to flash off sufficient hydrocarbon vapor to carry overhead the HF present in solution in the charge and also that formed by decomposition of organic fluorides. This flashing takes place in and above the steel ring section of the tower and the beds of aluminum rings below are left free to exert their catalytic defluorinating effect in the absence of free extraneous acid which if present would shift the defluorinating equilibrium and also shorten the life of the aluminum.

The features of this HF stripper have amply demonstrated their worth. Defluorinating efficiency started out at approximately 90 per cent (Fig. 3) and decreased gradually to a 60 to 70 per cent level, at which point the performance remained substantially constant, except for operating variables affecting fluoride content, until the end of the fifteenth month, at which time the unit was shut down for the first complete cleaning and inspection. During this period the rings had no cleaning of any sort; in fact, the tower had never been opened. Effective defluorination has meant considerably more to economical operation than merely through decreased HF acid and bauxite consumptions. In this regard, difficulties with silicon migration from the bauxite treaters to the deisobutanizer were nonexistent, due to low fluoride content of the stripper bottoms.

No Undue Corrosion

On the first inspection, after 15 months' operation, the deisobutanizer trays and overhead condenser showed no depositions of silica, nor have deisobutanizer reflux pumps shown any evidence of undue corrosion. It has never been necessary to draw water from the deisobutanizer reflux accumulator as the comparatively small amount of fluoride present in the stripper bottoms does not form sufficient water of reaction with bauxite to exceed the solubility of water in the deisobutanizer overhead. Since the HF stripper overhead returns directly to the contactors, in the operation of this plant at design rates, it is possible to adjust rates so as to minimize the amount of isobutane that must be defluorinated in the bauxite towers. This is accomplished by allowing the stripper overhead to furnish the recycle isobutane necessary to maintain the desired isobutane-olefin ratio with only the isobutane slip-stream to the depropanizer, plus any excess isobutane in the net feed entering the primary bauxite treaters. In this way economical operation is secured as acid losses in the treaters and bauxite consumption are at a minimum, yet ample defluorination of products leaving the acid area is maintained, thus making it unnecessary to handle acid in the fractionating area equipment.

The single-tower acid-regeneration system, in use since the beginning of operations, removed another source of trouble. The original two-tower regeneration systems had the inherent weakness of combating the corrosiveness of the acid-water mixture removed in the second or dewatering stage. Also, early systems had considerable instrumentation that was not only superfluous but a potential source of trouble. These points were considered in the design of the Corpus Christi unit and the acid-regeneration system was constructed as a single-tower unit floating on the acid settler, so that neither additional pumps nor pressure and level control instruments were required. This system has been very satisfactory. The use of isobutane as a stripping medium has made it possible to draw tar containing only extremely slight amounts of acid while refluxing the tower with isobutane allowed the production of high purity acid. Wartime rates of alkylate production were maintained with system acidities of 86-88 per cent while design rates are made with system acidities of 90-92 per cent. Water content of the acid is in the range of 1.0-1.5 per cent. Corrosion in the regeneration system has been mild. A welded Monel lining in the regeneration tower is giving excellent service although a steel tower, used earlier, did not suffer excessive corrosion.

The performance of packing in pumps, valves and control valves has been very satisfactory. Provisions for a flush oil (heavy alkylate) injection to lantern rings, controlled as to quantity by a differential pressure controller acting across an orifice in the flush line, has meant freedom from packing worries and good performance of instruments. Meters were sealed and trapped, as simply as possible, against acid and the seal pots and lines flushed at regular intervals. This has resulted in keeping the plant on automatic control and has meant much smoother operation with accurate control of process variables.

During the construction and in the early operation of the unit, a number of connections incorporated in the original design were dispensed with resulting in a decrease of some 150 acid-service valves. Only connections and valves of unquestionable utility remained. Valving in the unit as built was predominantly steel and, needless to say, constant intelligent servicing was required. One man on each shift was made responsible for a given group of valves and daily records kept of the condition of each one. In addition, each operator in charge of the shift was given the supervision of a group of valves which he checked over at intervals to make sure that proper servicing was being done. During each shutdown, valves that have become difficult to operate, or inoperable, are replaced with alloy trim valves, the majority of which have been trimmed in the refinery shops. Various combinations, including soft-steel plugs, Monel-lined plugs, and

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TABLE 1—PROCESS-AREA OUT-OF-POCKET COSTS. PERIOD: JULY 1, 1944, TO JUNE 30, 1945 INCLUSIVE

365 Calendar days—96.1% stream efficiency.
Alkylate production—1,988 bbl./calendar day

	$/CD
1. Operating labor—	
Direct supervision	$28.57
Direct labor	249.52
Indirect supervision*	3.82
Indirect labor*	75.83
Total operating labor	$357.74
2. Maintenance labor—	
Supervision	$15.41
Repair labor	192.42
Total maintenance labor	$207.83
3. Utilities—	
Steam	$154.32
Power	44.06
Water	107.73
Total utilities	$306.11
4. Operating supplies—	
Acid, HF	$278.69
Activated alumina	3.34
Bauxite	50.62
Lime, hydrated	6.77
Lime, quick	0.36
Caustic soda	15.38
Caustic potash	24.70
Clothing—laundry	2.60
Other	70.18
Total operating supplies	$452.64
5. Repair material	$282.75

*Includes laboratory control and inspection department.

RECAPITULATION

	$/Bbl.	$/CD
1. Operating labor	0.1800	357.74
2. Maintenance labor	0.1045	207.83
3. Utilities	0.1540	306.11
4. Operating supplies	0.2277	452.64
5. Repair material	0.1422	282.75
Total cost per day	0.8090	$1,607.07

finally stellited plugs plus Monel-lined bodies were tried with the latter found to be most satisfactory, and consequently adopted for final use. The gradual replacement has left few of the original plain-steel valves in service and valve servicing is far from the problem it once was.

Even though a process has demonstrated its worth during wartime, when the main emphasis was placed on ability to produce, it must present an attractive economic picture before its acceptance in peace time. Sufficient time has not elapsed to permit the presentation of true peace time HF alkylation costs; however, Table 1, covering out-of-pocket plant-area expenses for the first year of operation, indicates that HF alkylation costs are reasonable. With rates well above design, these chemical costs are high compared with peace time operation, as indicated in the opening paragraph. Maintenance, labor, and repair material costs for the first year are also abnormally high because of the necessity for the purchase and installation of alloy or alloy trim, valves, pump parts, and regeneration equipment needed to replace the original all-steel material. However, even with these abnormal expenditures, alkylate was produced for less than a $0.02 per gallon out-of-pocket cost, covering all process area operating and maintenance expense.

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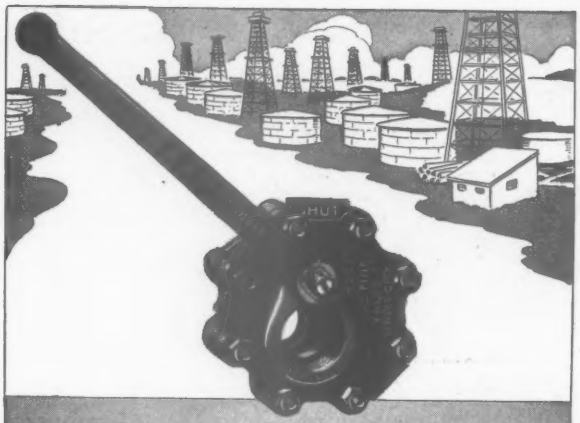

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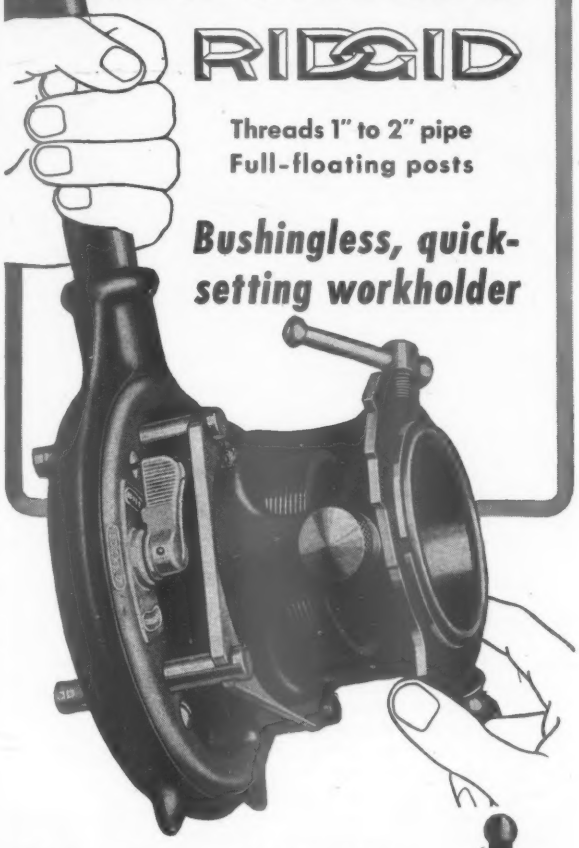

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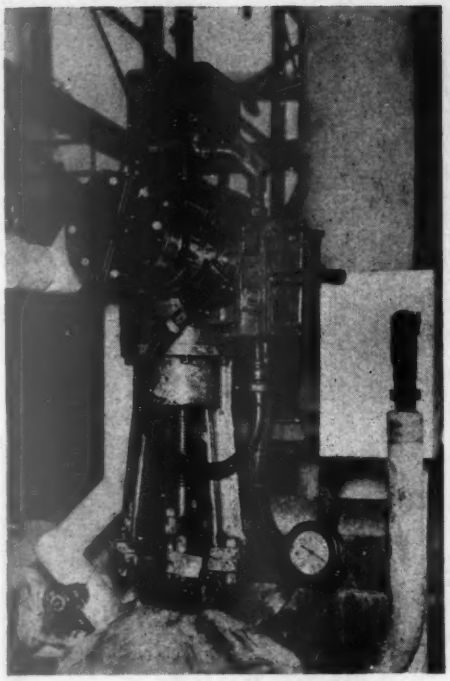


Fig. 1—(Extreme left) One of the original motor-operated valves—the first ever installed in an oil refinery—is still operating with precision at Sun Oil Co.'s Marcus Hook (Pa.) refinery

Fig. 2—(Left) Experimental valve used in testing new ideas for valve improvements at Sun Oil Co.'s Marcus Hook refinery

Motor-Operated Valves on Sun Houdry Unit in Continuous Service Since 1937

by Fabian R. Staley

THE first motor-operated valves ever installed in a large-scale Houdry catalytic cracking unit are still operating with precision after 9 years of continuous service. They are located in the Marcus Hook refinery of Sun Oil Co. When recently inspected these valves were in excellent condition although during this period they have opened or closed about 190,000 times.

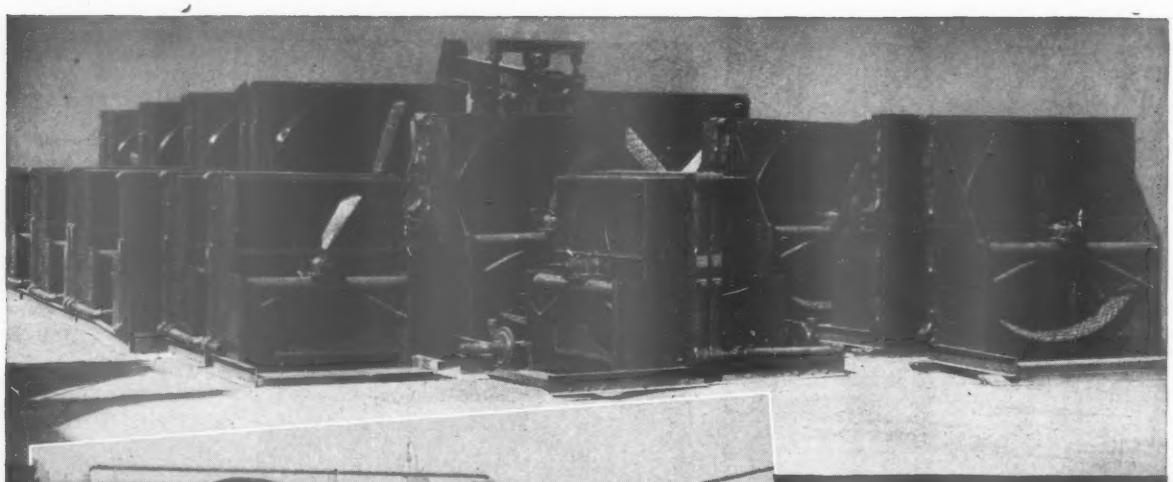
One 10-in. and three 12-in. valves are installed both on the top and on the bottom manifolds of each of the six catalyst cases of this unit, making 45 valves in all. The Houdry process employs a fixed-bed catalyst, and this is regenerated in place. The operating cycle of a case starts with the passage of oil vapors through the catalyst for a definite period of time, and at the end of this on-stream period the case is evacuated to a low pressure. It is then purged with steam, after which air is admitted to the case from a turbo compressor for the regeneration of the catalyst. The air is then evacuated and the case repressured to the oil system to complete the cycle of operation.

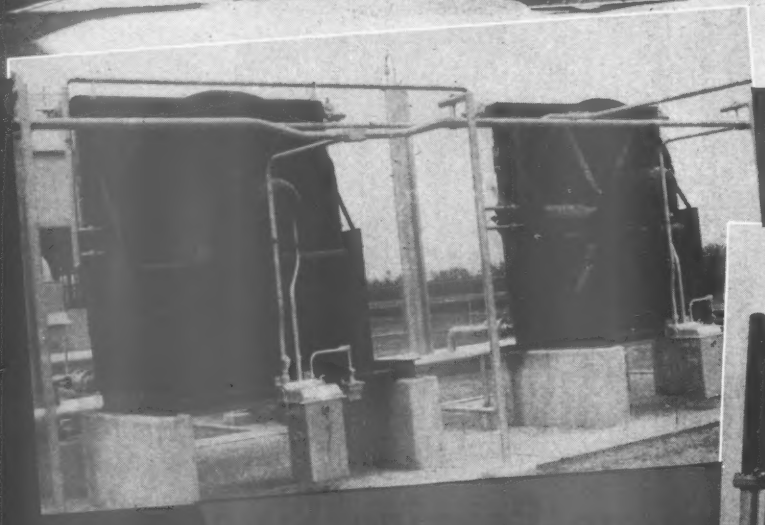
A cycle timer operates the valves at the top and bottom of each case. The valves must be closed before the succeeding ones in the cycle can operate. These valves have operated on 30 and on 45-minute cycles, and open or close in 9 seconds. An alarm is sounded automatically and a light is flashed if a ground occurs in either the control or in the power circuits. Thermocouple readings taken in various parts of the valves during operation show a maximum temperature of 740° F., although the maximum temperature of vapors passing through the valves may reach 900° F.

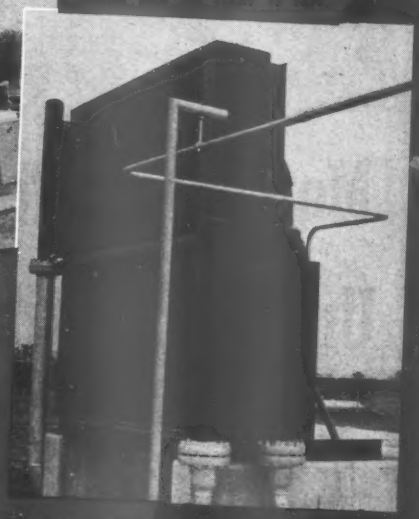
ONE weighty problem in the development of a practical commercial Houdry cracking process unit was the design of an automatic valve-switching system. This article shows how the motor-operated valves were designed, and how they are serviced. Valves operate under temperatures up to 900° F.; grease fittings are installed; 90-lb. steam is admitted to the valve bonnet to prevent oil-vapor leakage. Pressures of vapor seldom exceed 50 psi.

These valves have been developed by the engineering department of the Sun company with the cooperation of Philadelphia Gear Works, and various valve manufacturers including Walworth, Crane Co., The Wm. Powell Co., and Henry Vogt Machine Co. All sorts of operating mechanisms were investigated for the automatic operation of the valves. A complete assembly was set up in the shop, and operated for 10,000 cycles before the valves were installed in the plant. Since the original installation of these valves, larger ones have been built for other plants and some improvements have been incorporated such as housing the stem to keep dust and abrasive particles away from the threads.

In their construction, the valve bodies, size 8 in. and larger, are series







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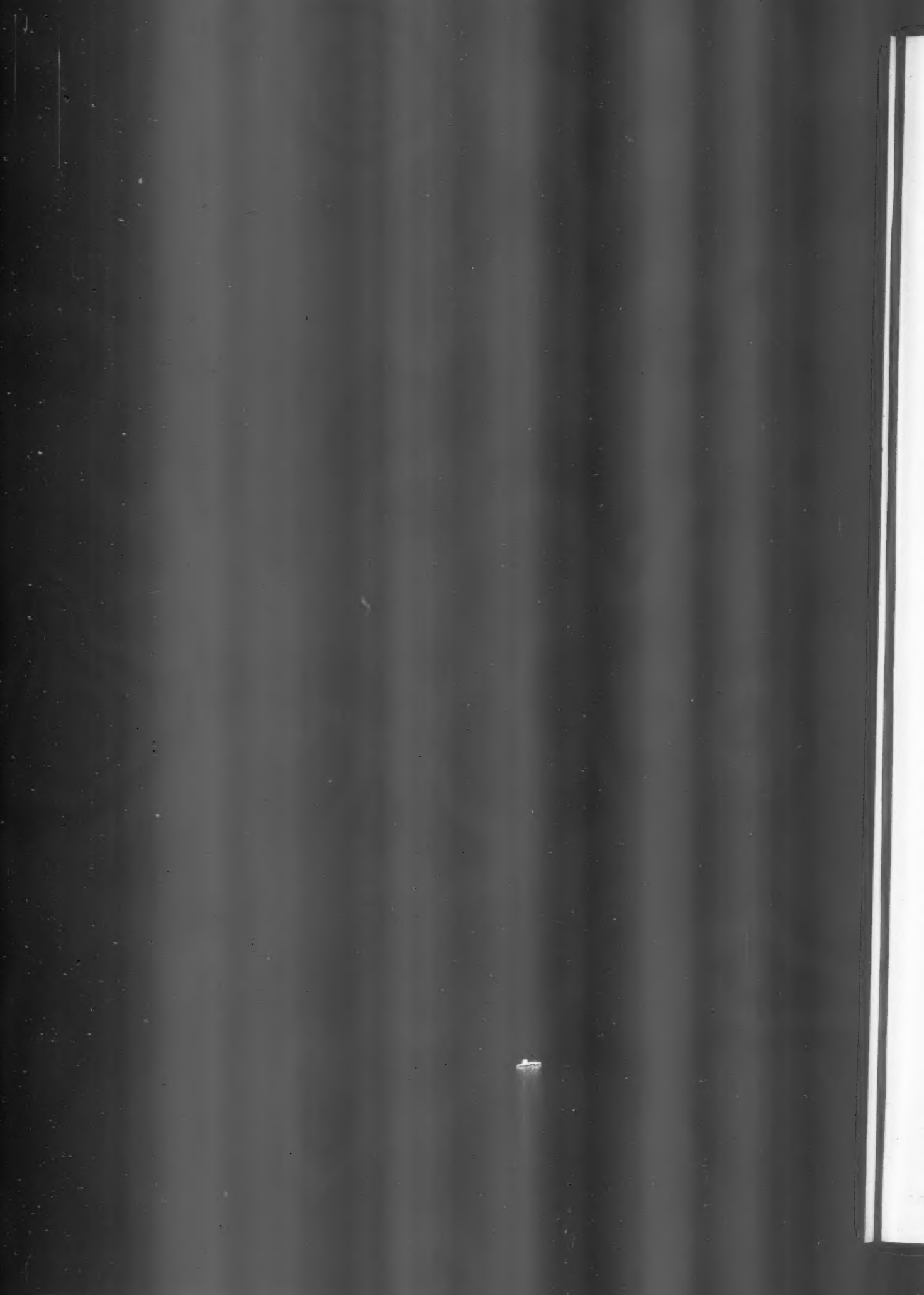


Fig. 3—(Left) Control panel of the first large-scale Houdry catalytic-cracking plant ever built. It is located at Plant 11-4, Marcus Hook refinery of Sun Oil Co.

Fig. 4—(Below) Sectional view of mechanism for actuating the valve stem, the torque switch in its compartment, the drum or sequence switch in its compartment, and the steam-sealing valve cam actuated from an extension rod screwed into the end of the valve stem

30, cast steel, and specifically reinforced and strengthened. Smaller sizes are made of forged steel. Valve seats and disks are hard-faced with Haynes stellite No. 6 rod. Sun specifications call for ⅛-in. thickness on both seats and disks, since it was found that 1/16-in. thickness was not sufficient. These faces are then ground. Valve stems are made of 11.5-13 per cent chrome steel. It was found that chrome plating flaked off and cut packing. Yoke nuts are made of nickel-bronze or manganese-bronze. Armco-iron ring gaskets are used for both the line and bonnet flanges.

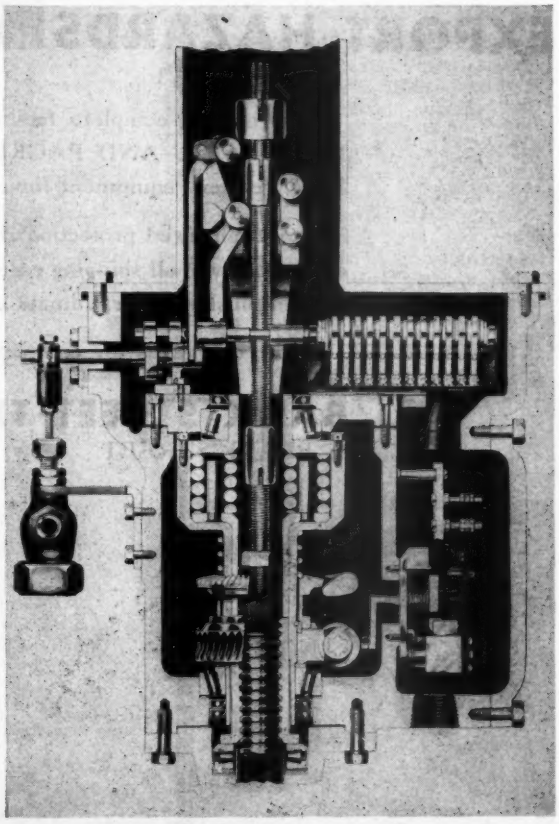
A grease fitting is installed on the valve for stem lubrication. When the valves are in the closed position, steam is automatically fed into the valve around the bonnet as a blanket to prevent leakage through the valve and the formation of an explosive mixture of air and oil vapor. This steam is under 90 psi., and the maximum line pressure of oil vapor or air does not exceed 50 psi.

Sun engineers believe that the excellent performance of these valves in general is due to their accurate machining, especially of the stem threads, and also to the selection of metals used in the various parts.

Control Mechanism

The control mechanism on these valves is built by Philadelphia Gear Works, and can be fitted to any sized valves up to 96 in. in diameter. An a.c. motor operates each valve, and a "hammer blow" device permits the motor to come up to full speed before the load is engaged. The hammer blow provides a force as much as 10 times that of the motor for unseating the valve disk. Valve-seating pressure can be varied up to 100 per cent by means of a torque switch which is controlled by means of a spring.

A small lever can be depressed for hand operation of the valve. This entirely disconnects the electrical drive from the unit, but when current is applied it automatically comes back to electrical operation. During electrical operation the handwheel does not rotate. In hand operation the drive is from the handwheel shaft pinion direct to the stem driving nut. Rotor of motor does not revolve during hand operation. The unit can always be operated manually in case of motor failure.



Sun's maintenance department has available facilities for setting up an entire valve assembly and then running mechanical and electrical checks on it. Specially trained mechanics and electricians are employed exclusively in valve-maintenance work.

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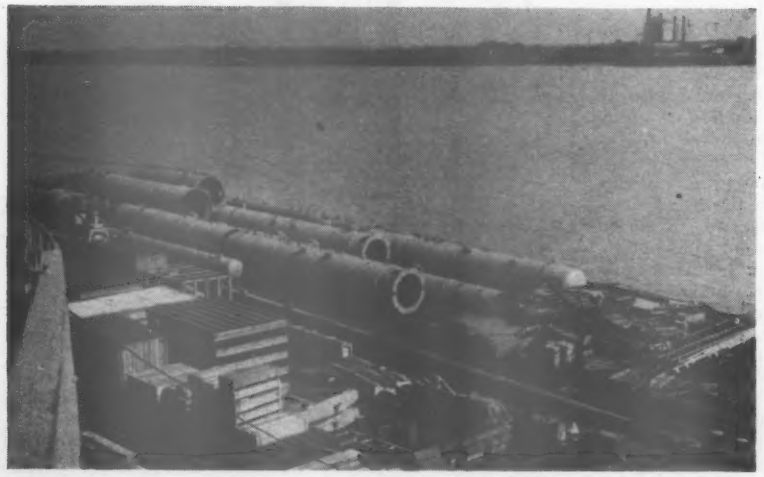

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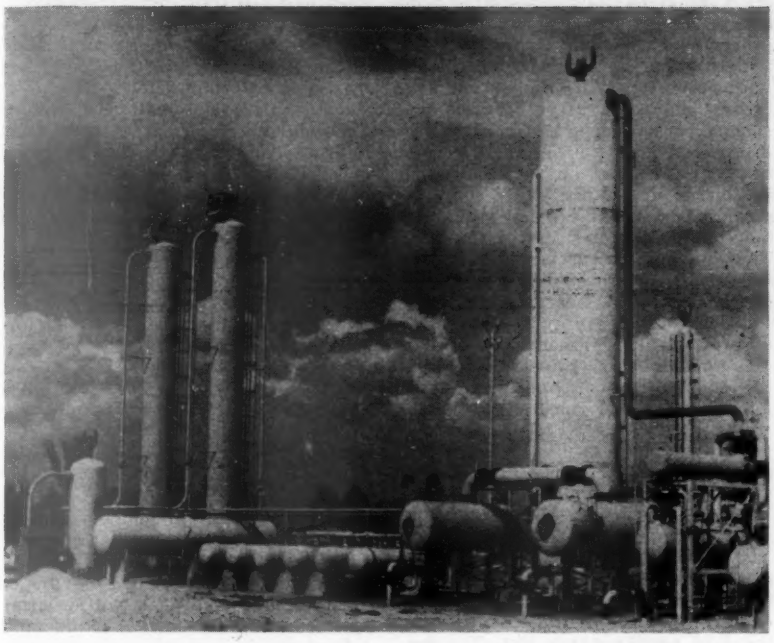


Fig. 1—Girbotol natural gas desulfurization plant of Arkansas Fuel Oil Co., Magnolia, Ark. Towers at left are twin absorbers; a single reactivator at right

Desulfurization of Petroleum Hydrocarbons

by R. M. Reed*

A number of organic sulfur compounds are found in petroleum and natural gas, either naturally or as result of processing changes made in the natural material. Eleven processes for removing hydrogen sulfide from hydrocarbon materials are discussed here, including the old Seaboard process, Thylox, Girbotol, and others. Mercaptans may be removed by oxidation to disulfides which does not lower the total sulfur content; or by processes such as Solutizer, Mercapsol, Unisol, caustic, etc. Gray, Houdry, and Perco processes remove sulfur compounds catalytically, as does the Union cobalt molybdate process, the last named developed especially for very high-sulfur-oil treatment.

MANY different sulfur compounds occur naturally in petroleum hydrocarbons, while others are produced during the various refining processes to which the hydrocarbons are subjected in the manufacture of commercial products.

In general, sulfur compounds are objectionable in most hydrocarbon products, since they may cause unpleasant odors, produce corrosion, or decrease the effectiveness of antiknock additives, and in addition will produce sulfur dioxide on combustion. However, in some cases, sulfur compounds have been added to hydrocarbons to modify their properties, as in the case of high-pressure lubricants, where sulfur compounds have been added to improve film strengths, and in the case of natural gas, where mercaptans are added as odorants.

This article presents a summary of sulfur compounds occurring in petroleum hydrocarbons, together with commercial methods available for desulfurizing various hydrocarbons.

A number of the sulfur compounds present in hydrocarbons are listed in Table 1.

TABLE 1—SULFUR COMPOUNDS IN PETROLEUM HYDROCARBONS

Compound—	Chemical formula
Alkyl disulfides	R_2S_2
Alkyl sulfides	R_2S
Carbon disulfide	CS_2
Carbonyl sulfide	COS
Hydrogen sulfide	H_2S
Mercaptans	RSH
Thiophane	C_4H_8S
Thiophene	C_4H_4S
Thiophenol	C_6H_5SH

In the above table, R signifies alkyl radicals, such as methyl, ethyl, etc. In addition to the compounds listed above, elemental sulfur is found at times in petroleum hydrocarbons, while a number of substituted thiophenes, thiophanes, thiophenols (aryl mercaptans), and other more complex sulfur compounds have been observed in hydrocarbons.

Hydrogen sulfide, thiophenols, and mercaptans are weak acids, and will form salts with alkalis. Carbonyl sulfide and carbon disulfide are essentially nonacidic, but will hydrolyze slowly to hydrogen sulfide. All the other compounds are nonacidic and will not react to any extent with alkalis.

Hydrogen sulfide and mercaptans are ordinarily the most objectionable sulfur compounds present in hydrocarbons, since they have strong odors and are actively corrosive under certain conditions.

Methods for Hydrogen Sulfide Removal[1,2]

The boiling point of hydrogen sulfide, —79° F. at atmospheric pressure, lies between those of ethane and propane, so that hydrogen sulfide may be removed quite effectively from higher boiling hydrocarbons, such as gasoline, by fractionation.

Chemical processes are ordinarily employed for removing hydrogen sulfide from hydrocarbons in cases where fractionation is not applicable. The principal chemical processes that have been utilized for this purpose are listed in Table 2.

Caustic soda solution and lime slurries are ordinarily not utilized on a large scale because of the cost of

TABLE 2—CHEMICAL PROCESSES FOR HYDROGEN SULFIDE REMOVAL

1. Caustic soda—$2\,NaOH + H_2S \rightarrow Na_2S + 2\,H_2O$
2. Lime—$Ca(OH)_2 + H_2S \rightarrow CaS + 2\,H_2O$
3. Iron oxide—$FeO + H_2S \rightarrow FeS + H_2O$; $FeS + \frac{1}{2}\,O_2 \rightarrow FeO + S$ (Second reaction promoted by contact with air)
4. Seaboard—$Na_2CO_3 + H_2S \rightleftarrows NaHCO_3 + NaHS$ (Reaction reversed by air blowing)
5. Thylox—$Na_4As_2S_2O_5 + H_2S \rightarrow Na_4As_2S_4O + H_2O$; $Na_4As_2S_4O + \frac{1}{2}\,O_2 \rightarrow Na_4As_2S_5O_4 + S$ (Second reaction produced by air blowing)
6. Girbotol—$2\,RNH_2 + H_2S \rightleftarrows (RNH_2)_2\,S$ (Reaction reversed by steaming)
7. Phosphate—$K_2PO_4 + H_2S \rightleftarrows KHS + K_2HPO_4$ (Reaction reversed by steaming)
8. Phenolate—$NaOC_6H_5 + H_2S \rightleftarrows NaHS + C_6H_5OH$ (Reaction reversed by steaming)
9. Alkacid — $RCHNH_2COONa + H_2S \rightleftarrows RCHNH_2COOH + NaHS$ (Reaction reversed by steaming)
10. Houdry—$NiO + H_2S \rightarrow NiS + H_2O$; $NiS + 1\frac{1}{2}\,O_2 \rightarrow NiO + SO_2$
11. Vacuum carbonate—$Na_2CO_3 + H_2S \rightleftarrows NaHCO_3 + NaHS$ (Reaction reversed by vacuum steaming)

*The Girdler Corp

the reagents and the problem of disposal of the sulfides produced.

Iron oxide impregnated on wood shavings is frequently used for removing hydrogen sulfide from hydrocarbon gases. The oxide reacts with the hydrogen sulfide to form iron sulfide. After the oxide has been spent, it may be regenerated by exposure to air, which oxidizes the iron sulfide to iron oxide and liberates free sulfur. The accumulated sulfur gradually reduces the activity of the iron oxide, which must be replaced from time to time. This process is quite effective for the removal of hydrogen sulfide from gases, but the labor costs for handling the iron oxide become excessive in installations where large quantities of hydrogen sulfide are removed from the gases being purified. Procedures have been developed for the regeneration of the iron oxide in place, either continuously by the addition of air to the gas stream being purified, or by recirculating gas containing air over the oxide beds. Some consideration is being given at present to the commercial recovery of sulfur from spent oxide, and a number of patents have been issued disclosing various procedures for the solvent extraction of spent oxide for sulfur recovery.

Seaboard Process Described

The Seaboard process, developed by The Koppers Co., was the first widely used hydrogen sulfide removal process employing a liquid absorbent that could be regenerated. In this process, the gas is contacted with a dilute solution of sodium carbonate, and the absorbed hydrogen sulfide is removed from the solution by blowing air through it. The hydrogen sulfide passes off in the air stream and is not recovered or utilized. The first commercial installation using this process was made in 1921, and more than 50 others have been built since that time. Several Seaboard plants treating natural gas have been converted to the Girbotol process in the last few years in order to effect more complete removal of hydrogen sulfide.

The Koppers Thylox process utilizes a sodium thioarsenate solution for removing hydrogen sulfide from gases. On blowing air through the solution after it has absorbed hydrogen sulfide, the thioarsenate is regenerated and elemental sulfur is produced. This process was first operated commercially in 1926. It has been used for purifying coke-oven gas and water gas more than for petroleum hydrocarbons, and a number of plants are in operation at the present time. The sulfur produced by these plants amounts to about 70 tons per day.

The Girbotol process of The Girdler Corp. employs solutions of amines for separating hydrogen sulfide from hydrocarbons. The first commercial installation for the purpose was made in 1930. At the present time, more than 100 Girbotol plants are in operation removing hydrogen sulfide from hydrocarbon gases and liquids. This process has become the one most widely used for this purpose, both with respect to the number and size of the plants that are in use. The removal of hydrogen sulfide from hydrocarbon gases or liquids by the process is carried out by contacting the gases or liquids with solutions of amines (organic alkalis) which remove the hydrogen sulfide from them. The absorbed hydrogen sulfide is then separated from the amine solution by heating, which regenerates the amine solution for further hydrogen sulfide absorption. This regeneration takes place because the amine sulfides dissociate readily at slightly elevated temperatures and release the hydrogen sulfide that has been absorbed at lower temperatures. The widespread use of the process has resulted principally from two factors. The first is that it is the only commercial process using liquid absorbents that has been utilized for purifying gases to the degree commonly required for pipe-line distribution, namely, to a negative test for hydrogen sulfide by the lead acetate paper test. The second factor is that the operating costs of the process have been lower than those with other processes, primarily due to the smaller steam requirements for regenerating the solutions. The hydrogen sulfide removed from the hydrocarbons is recovered in concentrated form, and may be utilized for the production of elemental sulfur, sulfuric acid, or other purposes. At the present time, hydrogen sulfide recovered from Girbotol plants is being converted to elemental sulfur in two cases, while two plants use it for producing sulfuric acid, one plant utilizes it for making sodium hydrosulfide, and one plant utilizes it in the manufacture of mercaptans for industrial purposes.

The total amount of hydrogen sulfide utilized in these ways is well in excess of 100 tons per day, which is a considerably higher sulfur recovery than is effected by other processes.

The phosphate process, developed by Shell Development Co., employs a solution of tripotassium phosphate for removing hydrogen sulfide from hydrocarbon gases or liquids. This is regenerated by steaming in a manner similar to that employed with the Girbotol process. This process has been used with refinery gases more than with natural gas.

The Koppers Phenolate process utilizes a solution of sodium phenolate for removing hydrogen sulfide from gases. Steaming is used for regeneration. Several plants were installed to use this process but most of them have since been converted to the Girbotol process.

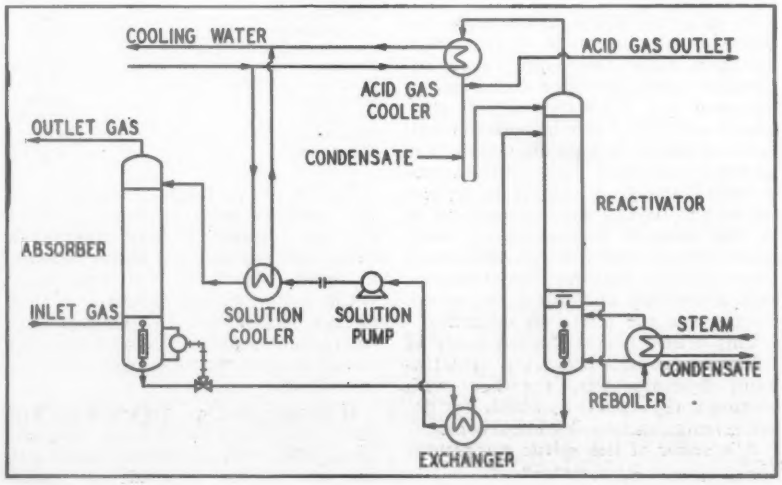
The I. G. Alkacid process uses solutions of the sodium salts of amino acids for hydrogen-sulfide removal. This process was developed in Germany and has not been used commercially in the United States.

The Houdry process, of Sun Oil Co., for removing hydrogen sulfide from hydrocarbons uses nickel oxide on a refractory support at a temperature of 700° to 800° F. The nickel sulfide is reconverted to nickel oxide by air blowing at the same temperature. The operation is intermittent, with multiple chambers being used. The process has been operated in a pilot plant, but has not been reported as operating commercially.

The Koppers vacuum carbonate process is a modification of the Seaboard process, using vacuum steaming for regenerating sodium carbonate solution that has absorbed hydrogen sulfide. It has the advantage over the Seaboard process that the hydrogen sulfide may be recovered in concentrated form. The process has not yet come into general use.

In addition to the hydrogen-sulfide-removal processes listed in Table 2 and described above, a number of

Fig. 2—Typical flowchart of desulfurization processes using steam for regeneration of treating agent



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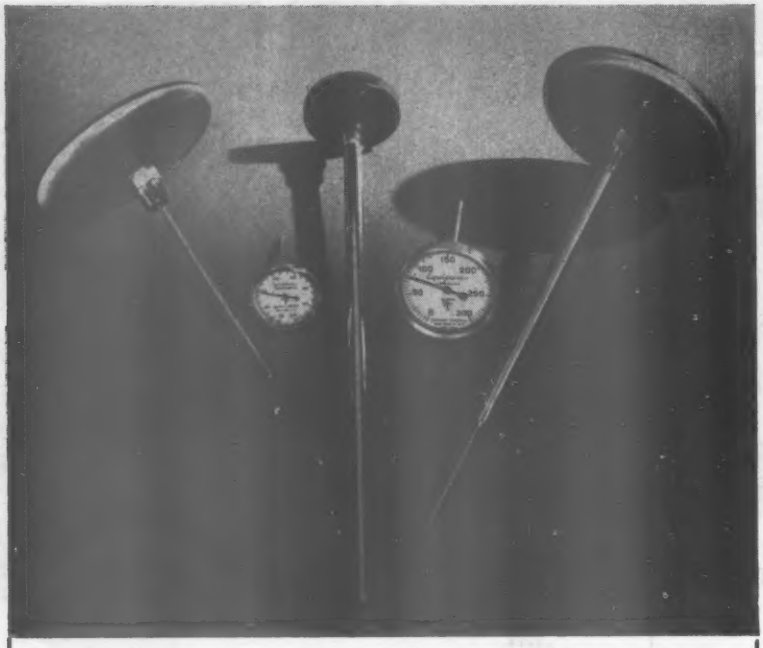

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other devices have been employed, such as the use of activated charcoal, silica gel, alkaline solutions containing, copper-chloride, hypochlorite, others, but none of these are in general use.

Methods for Mercaptan Removal[2,4,6,7,8]

Mercaptans are found in practically all hydrocarbons, since the different homologues have widely varying boiling points. Methyl and ethyl mercaptans are found in natural gas and refinery gases, while these and higher molecular-weight mercaptans occur in gasoline and other distillates. The various processes available for removing mercaptans from gasoline have been summarized by Happel, Cauley, and Kelly.[2] These processes fall into three types, (1) those which chemically convert mercaptans to disulfides; (2) those which remove mercaptans but which do not affect materially other sulfur compounds, and (3) those which remove some or all of the different types of sulfur compounds.

Processes of Type 1 do not decrease the total sulfur content of the gasoline, but merely oxidize the mercaptans to disulfides which have less objectionable odors than mercaptans. These processes include doctor-treating, copper-chloride, hydochlorite, and lead-sulfide processes. The sulfur content may be increased slightly by doctor treating.

Processes of Type 2 are regenerative, and actually remove the mercaptans from the gasoline. They are operated in a manner similar to the liquid absorbent processes described under hydrogen-sulfide removal. Both steam regeneration and air blowing are employed. These processes include the regenerative caustic process, the Shell Solutizer process, the Pure Oil Mercapsol process; the Atlantic Unisol process, and the Socony-Vacuum Tannin Solutizer process.

The regenerative caustic process uses a caustic-soda solution which reacts with mercaptans to form sodium mercaptides. These are separated from the solution by steam stripping. This process is quite effective for removing low molecular-weight mercaptans such as methyl and ethyl mercaptans from gasoline and other hydrocarbons, but does not give good results with high molecular-weight mercaptans.

The Shell Solutizer process uses a caustic solution containing solubility promoters such as sodium or potassium isobutyrate or alkyl phenols. These increase the solubility of the high molecular-weight mercaptides in the gasoline and make possible substantially complete mercaptan removal. Regeneration is by steam stripping.

The Pure Oil Mercapsol process employs mixtures of naphthenic acids and other organic compounds such as alkyl phenols for solubility promoters in caustic solutions for mercaptan removal. Steam stripping is also used for regeneration of the solution.

The Atlantic Unisol process[4] uses

methanol as a solubility promoter for caustic-soda solutions for mercaptan removal. Steam stripping is used for regeneration, with provision for substantially complete methanol recovery.

The Socony-Vacuum Tannin Solutizer process[8] uses a caustic-soda solution containing solubility promoters similar to those used in the Shell Solutizer process. Regeneration is effected by air blowing at low temperature (130° F.) in the presence of about 1 per cent of tannin which catalyzes the oxidation of mercaptides to disulfides. The disulfides are insoluble in the caustic solution and separate from it as an oil. The cost of regeneration by air blowing in this process is materially less than the cost of regeneration by steam in the other processes.

One of the principal advantages of the Type 2 over the Type 1 processes is the fact that the sulfur content of the gasoline is reduced by the Type 2 processes. Whereas disulfides do not have the objectionable odors of mercaptans, it has been found that they are sometimes even worse than mercaptans in their effect in reducing the effectiveness of lead tetraethyl for increasing the octane value of gasoline. In one case[9] it has been reported that while gasoline sweetening by doctor treating showed a processing cost of $0.0109 per barrel as compared with $0.0039 for Tannin Solutizer treatment, the difference in lead tetraethyl requirements to bring the two treated gasolines to the same octane value was such that the net cost of the doctor treatment was $0.0643 per barrel greater than for the Tannin Solutizer treatment.

The Type 3 mercaptan-removal processes include sulfuric-acid treating, catalytic-desulfurization processes, and catalytic-hydrogenation processes. In addition to mercaptans, they remove many other sulfur compounds as well.

Sulfuric acid has been widely used for refining gasoline, and oxidizes mercaptans to disulfides which are somewhat soluble in the acid, and are partly removed thereby. Partial removal of various other sulfur compounds is also obtained.

A number of catalytic-desulfurization processes are in use, in which hydrocarbons are passed over catalysts at elevated temperatures (about 700° F.). Mercaptans and many other sulfur compounds are converted to hydrogen sulfide, which may then be removed from the hydrocarbon by any suitable process. These processes include the Gray catalytic-desulfurization process which uses clay as the catalyst, the Houdry catalytic-treating process, which employs a special special catalyst, and the Perco process, which utilizes bauxite as a catalyst. The catalysts gradually become inactive, and may be regenerated by air blowing to burn off accumulated carbon and sulfides, although with bauxite and clay it is sometimes more

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economical merely to replace the catalyst as it is spent. Operating temperatures are kept low enough to avoid any substantial cracking of the hydrocarbons, though some polymerization of unsaturates will occur. A number of patents have been issued in recent years covering various modifications of these catalytic-desulfurization processes, such as the use of a charcoal catalyst activated by alkalis, two-stage operation at varying temperatures, quenching procedures, etc., which indicates that research and development work is continuing actively in this field.

Catalytic-hydrogenation processes for desulfurization operate under conditions similar to the catalytic-desulfurization processes described above, namely, with the hydrocarbon vapors being passed over catalysts at temperatures in the vicinity of 700° F., except that hydrogen is added to the hydrocarbons to aid in the conversion of organic sulfur compounds to hydrogen sulfide. Excess hydrogen is separated from the hydrocarbons by fractionation or oil absorption, the hydrogen sulfide is scrubbed out of it by any suitable means, and the hydrogen is recycled to the catalytic reactors together with the necessary makeup hydrogen. Various catalysts have been proposed for promoting the hydrogenation of organic sulfur compounds to hydrogen sulfide. The Union Oil Co. cobalt molybdate process[7] employes a cobalt molybdate catalyst. This process has not been operated commercially as yet, but extensive pilot-plant operations show that it is a very promising method for the desulfurization of hydrocarbons containing relatively large percentages of sulfur compounds (as much as 3-4 per cent sulfur) that are not readily removed by other desulfurization methods. Other catalysts employed for the removal of sulfur compounds by hydrogenation include molybdenum sulfide and thiotungstates. The Hydroforming process[8] was originally utilized primarily as a desulfurization process in some cases, although it operates at temperatures high enough so that extensive cracking of hydrocarbons, with simultaneous production of aromatics and hydrogen takes place. The sulfur compounds react with the catalyst to a considerable extent to form sulfides, which are converted to sulfur dioxide and removed during the regeneration with air blowing, which also burns off accumulated carbon from the catalyst. The Hydroforming process was used on a large scale for the production of toluene during World War 2.

In general, catalytic-hydrogenation processes for sulfur removal supplement the straight catalytic-desulfurization processes, and are utilized in cases where the sulfur content is so high, or the sulfur compounds are such (heterocyclic sulfur compounds) that they are not removed satisfactorily by the straight catalytic-desulfurization processes. These processes appear likely to come into more general use with the increasing utilization of high-sulfur petroleums, such as the West Texas, California, and Mexican crude oils.

In connection with the subject of mercaptan removal, it should be pointed out that the successful operation of processes of Types 1 and 2 require the prior removal of hydrogen sulfide from the hydrocarbons, since the reagents employed all will react with hydrogen sulfide, and in many cases form sulfides that cannot be readily regenerated. With processes of Type 3, hydrogen sulfide removal is desirable, but is not absolutely essential.

Removal of Other Sulfur Compounds

In many cases no effort is made to remove sulfur compounds other than hydrogen sulfide and mercaptans from hydrocarbons, since most of the other compounds do not have particularly objectionable odors. However, recent information on the deleterious effect of various sulfur compounds on the tetraethyl lead susceptibility of gasolines has spurred attempts to develop economical methods for the removal of all sulfur compounds from gasoline hydrocarbons.

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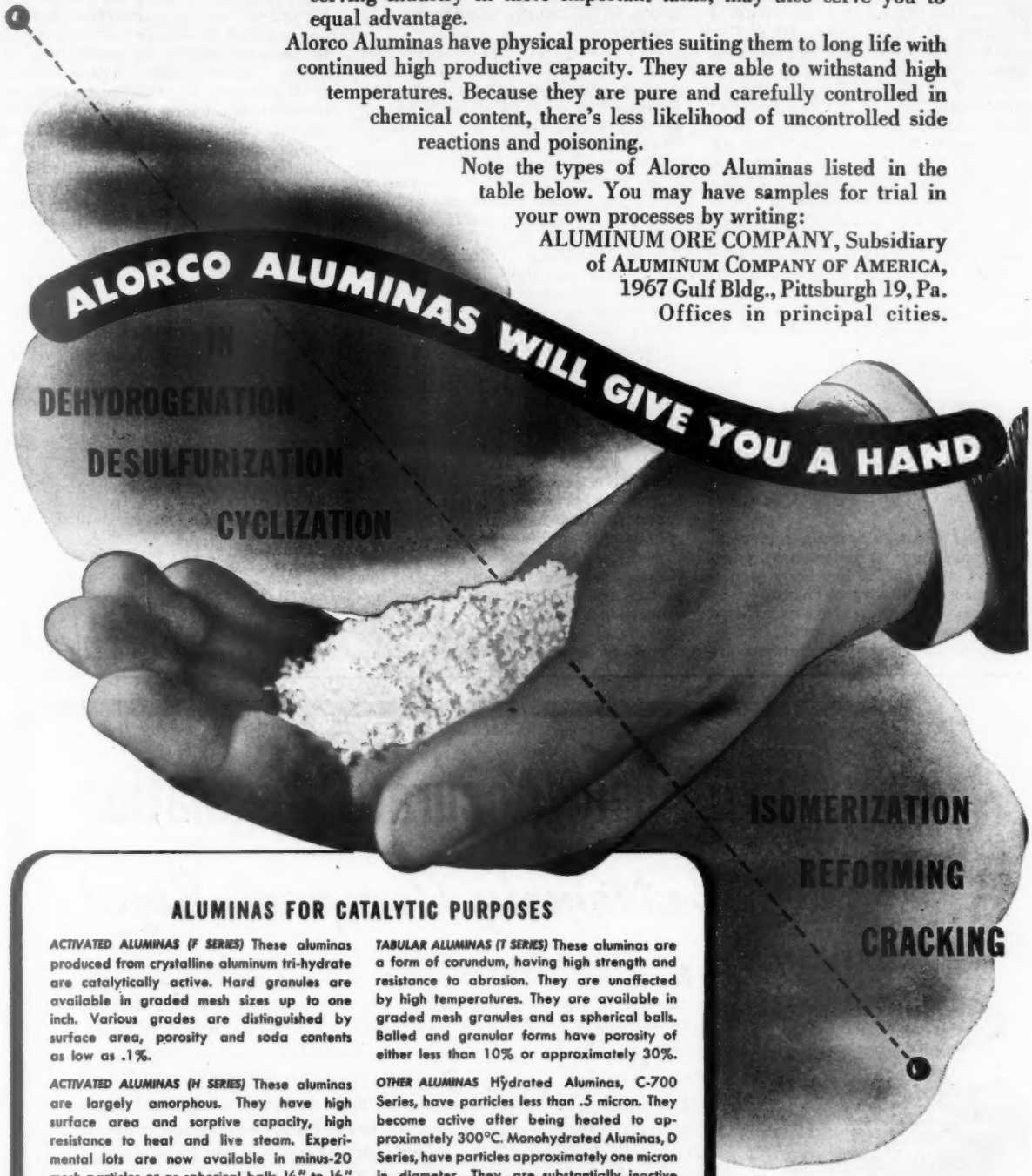

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does not occur naturally in petroleum hydrocarbons, but may be produced in cracking operation, and occurs at times in refinery gases. Its boiling point, —54° F. at atmospheric pressure, is very close to that of propane, (—48° F.), and carbonyl sulfide is quite often found in propane obtained from refinery gases. Chemical literature reports that carbonyl sulfide hydrolyzes readily in the presence of water to give hydrogen sulfide and carbon dioxide, but refinery operations indicate that it is relatively resistant to hydrolysis, since it has been found in appreciable quantities in propane that has been treated by the Girbotol process for hydrogen sulfide removal, followed by the regenerative caustic process for mercaptan removal, after which the propylene has been removed from the propane by sulfuric acid. Carbonyl sulfide may be removed from hydrocarbons by alcoholic caustic solutions, by primary amines, which react with it to produce ureas, or by the catalytic desulfurization or hydrogenation processes listed above, which convert it to hydrogen sulfide.

Carbon disulfide is not a very common constituent of petroleum hydrocarbons, although it has been reported as present in several cases. It may be removed by the processes utilized for carbonyl sulfide removal.

Thiophenols (aryl mercaptans) are acidic in nature, and may be removed from hydrocarbons by alkaline reagents, in a manner similar to alkyl mercaptans.

As has been mentioned above, most of the other sulfur compounds occurring in petroleum hydrocarbons may be removed, in part, at least, by catalytic desulfurization and hydrogenation processes.

Elemental sulfur may be removed from hydrocarbons by fractionation or by the doctor treatment, with the addition of mercaptans if none are already present. These react with sulfur in the doctor treatment to produce alkyl disulfides. Elemental sulfur is ordinarily present in hydrocarbons only in traces, its most likely source being from the oxidation of hydrogen sulfide to sulfur and water.

The accompanying flow diagram for desulfurization processes using steam regeneration is typical of the Girbotol, phosphate, phenolate, alkacid and vacuum carbonate processes for hydrogen-sulfide removal, and the regenerative caustic, Solutizer, and Mercapsol processes for mercaptan removal. Absorbers and reactivators are usually bubble tray or packed towers, arranged for counter-current flows of gases and liquids. Similar absorbers may be used for treating hydrocarbon liquids, using towers with packing or perforated plates, with the absorbent solution as the continuous phase, and with the absorbent liquid level maintained near the top of the tower. Orifice or mechanical mixers and settling tanks are also employed to provide multistage contacting in plants treating liquid hydrocarbons. In the Unisol process for mercaptan removal, the cycle is similar to that shown, with additional equipment for recovering methanol from the stripping steam and from the purified hydrocarbons.

Desulfurization processes using air for regeneration, such as the Seaboard, Thylox and Tannin Solutizer processes, employ absorbers similar to those shown above, but reactivate the solutions in suitable contactors.

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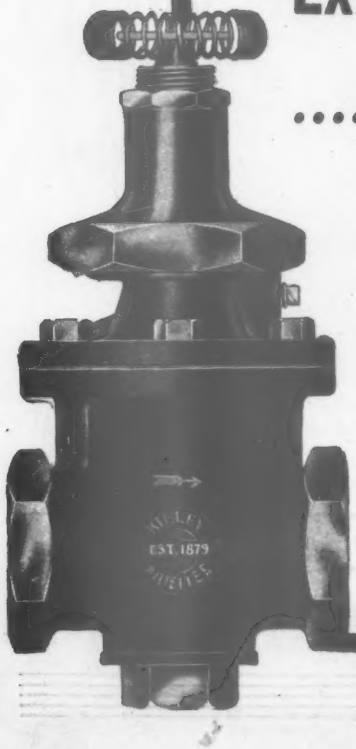

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Propane Deasphalting Process

by C. W. Kraemer

A 14,250-bbl. deasphalting unit has been in operation by Cities Service Refining Corp. since May 1944, and has been found to yield satisfactorily good catalytic-cracking-unit charge stocks of all gas oil up to 2.5 per cent residual material, based on original crude. Residual carbon content of the deasphalted oils is 2 per cent or less. The average cracking stock of boiling range above No. 2 furnace oil shows residual carbon of 0.5-0.8 per cent. Salt content of raw stocks is reduced to less than 2 lb. per barrel, in this case reducing the salt content of the total cracking charge to less than 1 lb. per barrel.

THE use of liquid propane as a refining agent to precipitate wax, resins and asphaltic materials from crude residuum for the purpose of producing stock for processing into lubricating oils has been widely accepted by the petroleum refining industry for a number of years. However, the adaption of the propane-deasphalting process to the processing of reduced crude in order to increase the amount of virgin heavy gas oil recoverable from crude oil to be used as feed stock for catalytic cracking has been comparatively recent.

Probably the first commercial deasphalting unit to be employed for the purpose of recovering virgin heavy gas oil catalytic cracking feed stock from crude residuum, is the 14,250 bbl. per day unit, put on stream in May 1944, at the Lake Charles, La. plant of the Cities Service Refining Corp. Separation of the heavy gas-oil fraction from the crude residuum from the topping units by liquid-propane deasphalting is somewhat of an innovation when compared with the somewhat older process of vacuum distillation, but offers certain desirable features obtainable only with great difficulty in the latter method of cracking-stock preparation.

The fact that high yields of quality products are obtained from the cracking of the heavier virgin gas-oil fraction of crude makes it necessary to maximum economy of refinery operation that the miximum quantity of the fraction be removed from the crude residuum. It is also necessary that the residuum carbon content of the total feed stock to catalytic cracking be held to a minimum in order to obtain high rates of cracking. The rate of cracking is generally limited by capacity for burning the carbon deposited on the cracking catalyst and, further, since it is known that certain metallic salts will poison the cracking catalyst it is desirable that the salt content of the cracking feed stock be reduced to a minimum.

The propane-deasphalting process is quite satisfactory in all the above respects since it will:

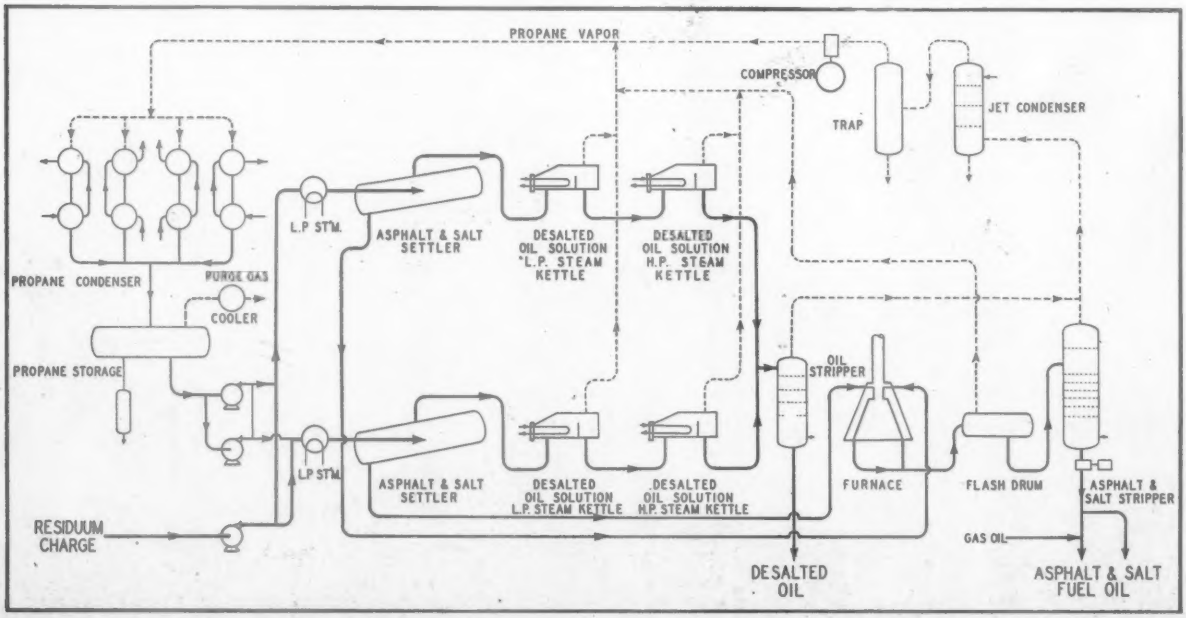
C. W. Kraemer is a process engineer with Cities Service Refining Corp. at Lake Charles, La. Kraemer received his bachelor's degree in chemical engineering at Rose Polytechnic Institute in 1932 and served in the operating departments of Velsicol Corp. and The Rock Island Refining Corp. and in the development department of U. S. Rubber Co. before joining Cities Service in 1944.

1. Make available to catalytic-cracking feeds all gas oil in excess of 2.5 per cent residuum based on average crude oil.

2. Produce deasphalted oils having 2 per cent or less of residual carbon content so that the average cracking feed stock of heavier than No. 2 furnace oil boiling range will have residual carbon contents of 0.5-0.8 per cent.

3. Produce deasphalted oils having total salt content of less than 2 lbs. per 1,000 bbl. of oil so that the above total cracking feed will contain less than 1 lb. of salt per 1,000 bbl. of oil and this in spite of wide variation in the salt content of the feed to the deasphalting process.

In utilizing liquid propane as a re-



Flow chart of desalting and deasphalting residuum for preparation of cracking stocks

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Cities Service propane-deasphalting unit, which prepares heavy gas-oil charge stock for Fluid catalytic-cracking units

fining agent, advantage is taken of the fact that as the liquid propane is mixed with the crude residuum in increasing proportions, a critical point is reached at which separation of the residuum into two phases occurs, a gas oil-propane phase and an asphalt-propane phase. Propane to oil ratios in the neighborhood of 4:1 are usually satisfactory for good separation. Increasing the propane to oil ratio up to a certain limit tends to increase the efficiency of separation into the two phases.

Settler Temperature Varied

After the desired propane to oil ratio has been established, variation of the settler temperature is employed for control of product quality. Since settler operating temperatures are usually held within a narrow range, approximately 140° F. to 185° F., the liquid propane is just below its critical temperature when operating under a constant pressure of about 515 PSIA. As the critical temperature of the propane is approached over the narrow temperature spread, the affinity of the propane for holding the asphaltic constituents in solution becomes less and less so that at the critical temperature, the amount of materials held in solution by the propane is almost negligible. It is therefore evident that the control of the quality of the deasphalted gas oil and the asphalt may be accomplished by merely varying the temperature of the solution. Maximum gas-oil yield is realized at the lower temperature and minimum gas-oil yield is produced at the higher temperature. It is necessary that the propane and oil mixture be kept in the liquid state while in residence in the settlers, hence the high operating pressure. After the two phases are removed from the settlers, the process simply becomes a common one of evaporating and stripping the propane from the deasphalted gas oil and asphalt products, condensing the propance and returning it to intermediate storage for further recycling.

Propane was chosen for the differential solvent because, with it, products similar in nature and quality to those produced by vacuum distillation of the crude residuum may be obtained. It is necessary that propane of high purity be used due to the fact that if a lower molecular weight hydrocarbon solvent of the methane series was substituted for propane under fixed operating conditions, practically all of the reduced crude bottoms would be precipitated out of the asphalt fraction. If, on the other hand, a higher molecular weight hydrocarbon of the methane series is substituted for the propane, at the same fixed operating conditions, the

TABLE 1

Operating Period	1	2	3	4	5	6
Yields						
Reduced crude charge, BPD	6,180	11,125	13,432	15,915	16,957	13,172
Deasphalted oil product, BPD	3,610	10,284	11,561	13,780	14,028	9,186
Per cent yield on charge	58.41	92.44	86.07	86.58	82.73	69.74
Asphalt product, BPD	2,570	841	1,871	2,135	2,929	3,986
Per cent yield on charge	41.59	7.56	13.93	13.42	17.27	30.26
Operating Variables						
Propane-to-feed ratio	4:1	4.33:1	4.5:1	3.9:1	4.0:1	5.2:1
Settler pressure, psig	512	512	505	505	505	505
Settler temperature, ° F.	184	146	154	156	149	149
Inspections						
Crude Residuum Feed						
Gravity, ° A.P.I.	21.3	18.8	18.9	19.2	18.4	17.2
Viscosity, S.U.S. @ 210° F.	106	168	....	....	....	....
Carbon residue, %	4.08	5.92	5.18	4.97	5.86	7.20
Salt, lbs./1,000 bbl.	....	106	123	162	205	218
Pour point, ° F.	110	....	89	89	83	90
Deasphalted Oil Product						
Gravity, ° A.P.I.	23.9	21.0	21.2	21.4	21.4	21.3
Viscosity, S.U.S. @ 210° F.	82.9	112	....	....	....	....
Flash point, ° F.	403	384	227	208	209	225
Carbon residue, %	2.04	2.87	2.39	2.53	2.51	1.98
Salt, lbs./1,000 bbl.	....	2	2	2	2	2
Pour point, ° F.	110	....	102	104	106	110
Asphalt Product						
Specific gravity	0.9371	1.0442	1.0045	0.9965	....	....
Penetration (100 g. 5 Sec. @ 77° F.)	....	....	90	93	....	....

TABLE 2

Operation with high salt content in residuum

Yields	BPD	Salt Content Lbs./1,000 Bbl.	Total Lbs. Salt	Per Cent
Residuum charge	17,027	225	3,830	100.0
Gas-oil product	14,329	4.5	64	1.7
Asphalt product	2,698	1,385	3,736	97.5
Recovery			3,800	99.2

Operation at average salt content in residuum

Yields	BPD	Salt Content Lbs./1,000 Bbl.	Total Lbs. Salt	Per Cent
Residuum charge	15,915	162	2,462	100.0
Gas-oil product	13,780	2	29	1.1
Asphalt product	2,135	1,140	2,434	98.9
Recovery			2,462	100.0

quantity of material precipitated out in the asphalt phase would be considerably less than that precipitated by the propane. In other words, as the molecular weight of the solvent increases, the quantity of the asphaltic phase becomes smaller and smaller for a given type of reduced crude provided that the operating conditions remain constant. The characteristics of the products obtained by using the higher or lower molecular weight hydrocarbon solvents are radically different from those produced by the propane solvent. If a mixture of two solvents was used, propane and butane, for example, yields would be obtained that would fall in between those that would be realized by using one or the other of the two solvents in the pure state.

Flow through the unit at Lake Charles is shown in Fig. 1. The crude residuum from the topping units is picked up from intermediate storage by two turbine driven four-stage centrifugal pumps. Suction is also taken on the propane storage drum, which is held at 265 psig pressure, by two turbine driven three-stage, high speed, centrifugal pumps. The propane streams join the residuum streams in ratios of between 4:1 and 5:1 and are mixed prior to entering a tubular type feed preheater which employs low pressure exhaust steam as the heating medium. Since the residuum enters the battery limits at approximately 175° F., and since the propane cools the mixture to only a few degrees below the desired temperature, the duty of the preheaters is practically negligible when operating the settler at a temperature of 150° F. The propane-oil mixture enters the two settlers, in parallel, where separation into the two phases occurs. Pressure is maintained constant on the settlers at 505 psig by means of pressure recording controllers. Liquid level recorders indicate the level between the asphalt and gas oil phases and flow recording controllers maintain the level within the desired limits by varying the amount of the asphalt phase withdrawn from the bottom of the settlers. The asphalt settlers are 8 ft. I.D by 45 ft. drums mounted at an angle of approximately 6° from the horizontal. The interiors are arranged with perforated baffles spaced at regular intervals for the purpose of obtaining better separation between the gas oil-propane phase and the asphalt-propane phase. The asphalt product carries with it an almost equal volume of propane and is withdrawn from the lowest point of the settlers and is charged directly to a gas fired reboiler furnace where the mixture is heated to approximately 450°F. The heated mixture discharges to the asphalt flash drum where the major portion of the propane is flashed directly to the propane condensors. The propane vapors are condensed and returned to the propane storage or surge drum for further recycling.

The asphalt is then fed to a vertical stripper, operating at atmospheric pressure, where the remaining traces of propane are stripped out by means of 450° F. steam. The steam and the propane vapors are taken overhead to a jet condensor where the steam is condensed and withdrawn. The propane vapors are taken overhead through the compressor dry drum to one of the two 600-hp. two-stage compressors which compress the vapors to 285 psig. required to force the propane through the condensors and back into the liquid propane storage drum. The asphalt is removed from the stripper by means of a steam driven reciprocating pump. Heavy catalytically cracked cycle gas oil is blended directly into the discharge of the asphalt product pump in the proper proportions for production of No. 6 fuel oil.

The deasphalted gas oil-propane phase is withdrawn overhead from the asphalt settlers and discharges successively into two low temperature steam kettles and then into two high temperature steam kettles where the greater portion of the propane is flashed directly to the propane condensors. From the condensors, the liquefied propane returns to the propane storage drum. The deasphalted gas oil is then charged to a vertical atmospheric stripper tower similar to the one used for stripping the asphalt. The remaining traces of pro-

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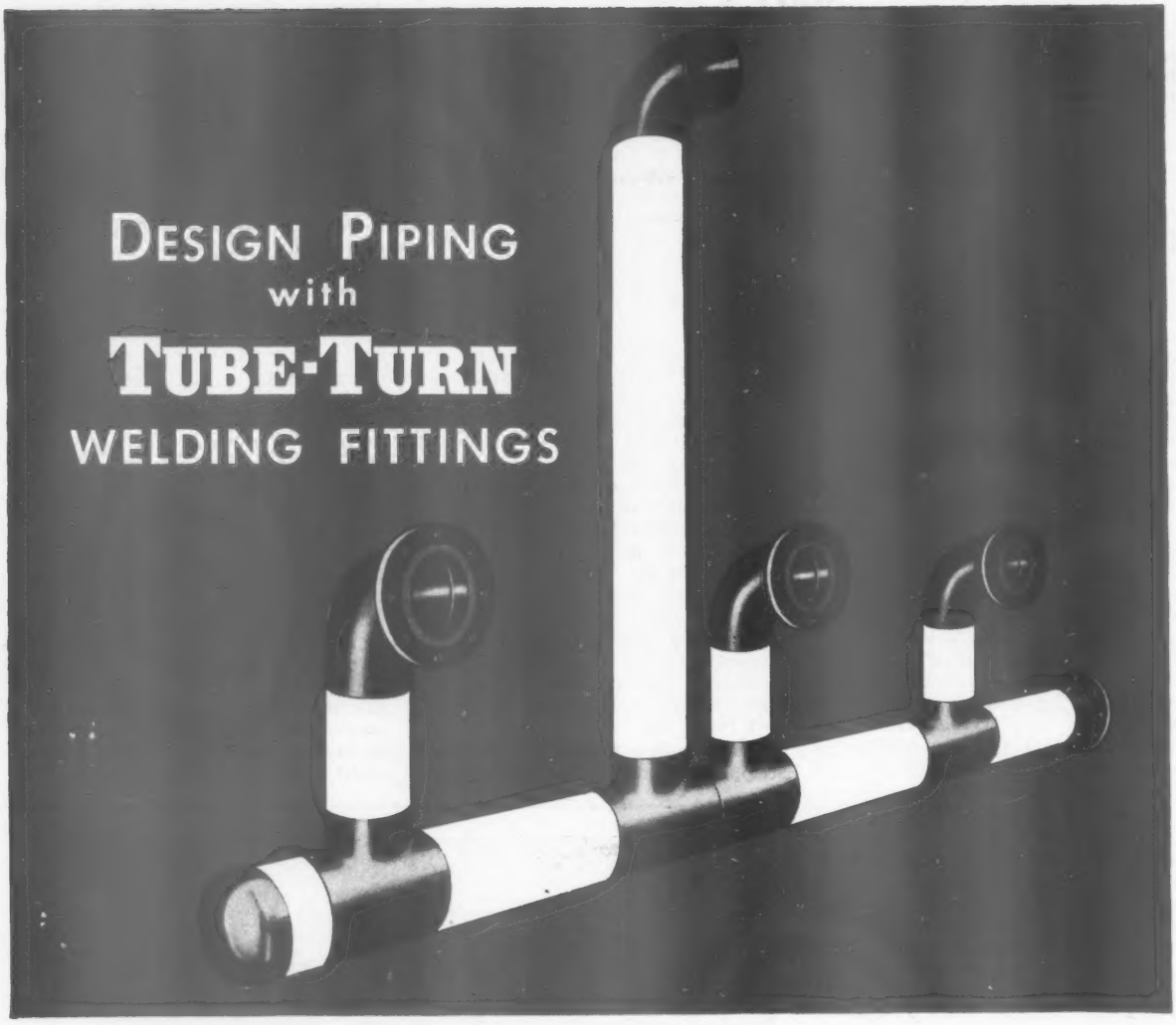

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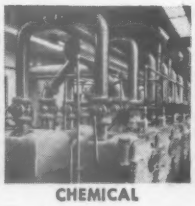
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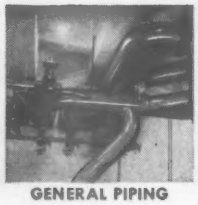
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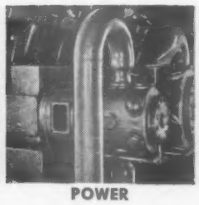
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EQUIPMENT

pane are stripped from the gas oil, by means of steam, into the jet condenser which serves both the gas-oil and the asphalt strippers.

The propane free deasphalted gas oil is removed from the stripper by means of a steam driven reciprocating pump and may either be segregated in intermediate storage tanks or be blended in various proportions with the heavy gas-oil fractions from the topping units to make up the feed stock for the catalytic cracking units.

Table I presents data covering yields and typical inspections of the feed and products when operating the unit at various rates of throughput, settler temperatures and propane-to-oil ratios. Normally the unit is operated to produce maximum yields of gas oil and consequently, the settler temperature is held between 140° and 150° F. Propane-to-oil ratios are usually maintained as high as the temperature of the propane condenser cooling water will permit. Operating Period 1 demonstrates what yields may be expected when operating at the higher temperature range.

Table 2 demonstrates the efficiency of the unit as a means of removing the salt from the heavier gas-oil fraction. It has been possible to consistently hold the salt content of the deasphalted gas oil at 2 lbs. and less of salt per 1,000 bbl. of oil.

The process, in addition to the product yield and quality advantages previously mentioned, is simple and economical in its operation. Net consumption of solvent is small and the solvent is cheap in itself, ordinarily having no alternate use value except as fuel.

S.A.E. Speakers to Discuss Fuel Problems in Aircraft

NEW YORK.—Several talks of interest to oil engineers will be given during the 3-day national aeronautic meeting opening April 3 at the Hotel New Yorker in New York under the sponsorship of the Society of Automotive Engineers.

"Fuel and Lubricating Oil Requirements for Personal Planes" will be discussed by C. T. Doman, Aircooled Motors Corp., the afternoon of April 4. S. D. Heron, Ethyl Corp., will speak on "Fuel Sensitivity and Engine Severity in Aircraft Engines" the afternoon of April 5. Another discussion April 5 is on "Utilization of the Exhaust Gas of Aircraft Engines" by Benjamin Pinkel, National Advisory Committee for Aeronautics.

Iran Production

NEW YORK.—Crude oil production for the entire month of November amounted to approximately 11,172,000 bbl., compared with about 11,161,000 bbl. for October.

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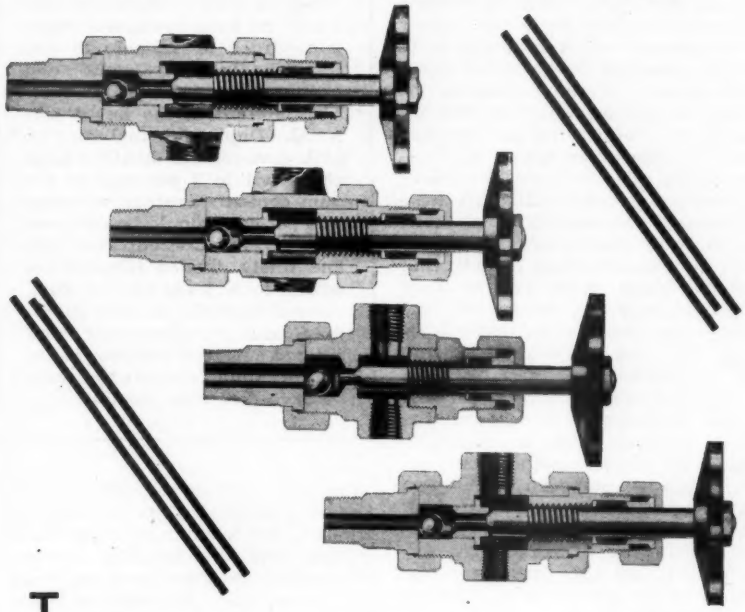

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The Acid Flocculation Test—

A Method for Determination of Gum Content of Heavy Distillate Fuel Oils

by W. A. Proell and J. A. Bolt

BY flocculating distillate fuel gums with hydrochloric acid a test has been developed which is regarded as suitable to distinguish between gums and heavy, low-volatility hydrocarbons present in the tested material. Duplicate analyses on high-gum-content distillate fuels check within 2 per cent of the gum content; average variation of 5 per cent should be obtained by analysts. Concentrated HCl and finely divided filtercel are added to a sample of fuel, carried through the test procedure, and the flocculated gum filtered out. Iron compounds are gum-forming catalysts and must be excluded from the test.

Introduction

FUEL-OIL technologists have recognized for many years that there is present in diesel fuels and burner oils a material which is analogous to gum in gasoline in its effect upon performance. Gummy deposits, formed on pumps, injectors, screens, nozzles, etc., affect the performance of the mechanism in which the fuels are utilized. The problem of predicting, evaluating, and mitigating malperformance is complex. If possible, any study of the problem should be based on measurements of only that material which gives rise to such malperformance. Considerable research[1,2] has been carried out on devising and using accelerated aging tests on fuel oils; but these tests can be justified only when a suitable method is available to measure the true gum formed. With an acceptable method for measuring the gum content, it will be comparatively easy to develop accelerated aging tests which will correlate with service performance. This paper presents a convenient method for this primary measurement of the gum content of heavy distillate fuels.

Most workers have considered gum determination in fuel oils to be similar to determination of gum in gasoline. They feel that the nonvolatile residue is the material which deposits on vital engine and burner mechanisms. Accordingly, attempts to determine the gum have been made by means of evaporation tests. The evaporations are effected at relatively high temperatures in the presence of an inert gas[3,4] or by vacuum evaporation in a stream of inert gas.[5] These authors recognize that the nonvolatile residue they call gum may contain material which is completely innocuous: additives, heavy lube oil, polymers, etc. One attempt to measure true gum departed from the evaporation technique by using alcohol to extract the gum from the oil.[6] Because of the poor selectivity of the alcohol, that method does not appear promising.

The method of determining gum in distillate or diesel fuels need not be analogous to that used with gasoline. With gasoline, any nonvolatile residue is an evident detriment to systems in which the fuel is partially or completely vaporized prior to injection into the combustion zone. In diesel engines and distillate-fuel burners, whose fuels are introduced in the liquid phase, only oil-insoluble materials can precipitate and foul the mechanisms prior to entering the combustion zone. Because of these inherent differences in the types of mechanism in which gasolines and heavier distillates are used, it seems quite obvious that methods of evaluating the gum content ought to differ in the two cases.

The proposed method, which is called the acid flocculation gum test, is based on the theory that the gum which deposits in fuel systems is present in the oil as a colloidal dispersion and can be flocculated by concentrated hydrochloric acid without causing a chemical change in the oil itself. The method consists in contacting an oil with the acid, filtering out the floc, washing it free of oil, and weighing. If the theory is correct, only oil-insoluble materials will be precipitated; oil-soluble materials, irrespective of molecular weight, will not be measured as gum.

Method

Filter the oil sample through a small, coarse filter paper to remove ordinary sediment. Transfer exactly 100 cc. of oil (20° C.) to a 250-cc. glass-stoppered graduated cylinder. Add 0.5 gram of dry, iron-free filtercel (see discussion). Then add 50 cc. of c.p. concentrated hydrochloric acid and wipe the mouth of the cylinder free of the filtercel. Stopper the cylinder and shake it vigorously for 2 minutes. Allow the cylinder contents to react for exactly 2 hours, shaking the cyl-

THE AUTHORS

W. A. PROELL

J. A. BOLT

Wayne Proell, a chemist, was born in Chicago in 1915. He graduated with the class of 1937 at University of Chicago, receiving his B.S. degree. After a short time with the electrochemical industry in Ohio, he joined the research staff of Standard Oil Co. of Indiana and worked 4 years in fuel-oil research. During the war he was engaged on special weapons development on a NDRC contract under Standard, until termination of the project in 1944. Since then exploratory petrochemical research has occupied his time. He is a member of Phi Beta Kappa and the U. S. Rocket Society.

J. A. Bolt was reared on a farm near Raymond, Minn. He received his A.B. degree from Calvin College in 1929, and his M.S. degree in chemistry from University of Michigan in 1930. In July of that year he joined the research department of the Standard of Indiana. He has carried out research on a large number of projects dealing primarily with light-oils finishing and with the burning properties of distillate fuels. He has obtained considerable background on the gumming tendencies of gasolines and of other light petroleum distillates. He is active in the C.R.C. gasoline additives projects, is a member of the A.S.T.M. group on stability, sedimentation, and corrosion of burner fuels, and is a member of American Chemical Society.

inder every 15 minutes by inverting it two or three times. At the end of the 2-hour period the gum will have been flocculated and will be ready to separate by filtration.

A glass filter tube is constructed, 55 cm. in length and 25 mm. in diameter, equipped with a drawoff 8 cm. long and 7 mm. in diameter. Attach this to a stand, put a small glass-wool plug in the bottom, and add about 2 grams of filtercel to the tube. Apply vacuum to the tube and tamp the filtercel down with a glass rod, to form a dense, coherent pad 0.75-1.0 in. thick. If the pad is not thick enough, add more filtercel. Then add 50 cc. of acetone, suck the filter dry, add 25 cc. of concentrated c.p. hydrochloric acid, and allow to stand until the flocculation step is complete.

When the oil is ready to filter, at the end of the 2-hour period, apply vacuum to the filter tube until it is sucked dry. Shut off the vacuum. Shake the graduated cylinder vigorously and pour its contents into the filter. Considerable mixed gum-filtercel may remain in the graduate; make no effort to remove this. Allow the acid mixture to filter through the filtercel pad by gravity for 10 minutes, and then apply a slight vacuum so as to pull the filter dry in 20 minutes more. Shut off the vacuum. Add to the graduate 50 cc. of hexane (see discussion), shake, and add to the filter in such a manner as to wash the walls of the tube. Allow the hexane to percolate through the filter by gravity for 3 minutes, then apply vacuum to pull the filter dry in an additional 3 minutes. Add 100 cc. of distilled water to the graduate, shake vigorously, and add to the filter as soon as the first hexane wash is completed. Allow to percolate by gravity for 3 minutes, then apply vacuum to pull it dry in 10 minutes. Wash the graduate again with 50 cc. of hexane, and add to the graduate as in the first hexane wash. Discard all filtrates. The gum is present chiefly on the filter, with some in the graduate, in a pure and oil-free state. It is now ready for recovery.

Add 50 cc. each of residue-free acetone and alcohol (95 per cent) to the graduate. Shake and allow to stand for a few minutes to dissolve the gum particles. In the meantime wipe the drawoff tube on the filter clean of oil and attach a 500-cc. filter flask. Pour the alcohol-acetone mixture into the filter tube, allow it to percolate 3 minutes, then suck it dry. Repeat using residue-free alcohol and chloroform (50 cc. of each), combining the filtrate with the previous filtrate of alcohol-acetone. Wash the drawoff tube with a little acetone, and allow the washings to fall into the combined filtrates. The filtrate now contains all the gum in solution. The filtercel should be white. Filter the gum solution through a small coarse filter paper (this removes any filtercel which may have escaped from the filter tube) and collect it in a beaker. Wash the empty filter paper with a little acetone; be sure no gum remains on the paper.

Two methods may be used to measure the gum at this stage. The most rapid technique is to evaporate the gum solution by the A.S.T.M. D381-42 test procedure. Because all the solution cannot be added to the gum beaker at one time, it should be added in increments as the evaporation proceeds. Do not allow the beaker to evaporate to dryness before all the solution has been added. Otherwise, the beaker will become too hot and will spatter when a new increment is put in. When the evaporation is complete, finish the test as described in the A.S.T.M. procedure. In some cases, where the gum is light and fluffy, the rate of air blowing should be reduced to avoid blowing the gum away, especially after the beaker becomes dry.

Where the A.S.T.M. apparatus is not available, the gum solution may be evaporated to dryness in conventional glass gum dishes on the steam bath, blowing with clean (filtered) air. In this case the dishes must be dried to constant weight at about 250° F., usually a matter of 4-10 hours.

Discussion

The filtercel (diatomaceous earth) used in the test is the low-flow-rate, fine type. It should be purified before use by washing with hydrochloric acid to remove traces of iron. Ferric chloride was found to be a catalyst which accelerated gum formation, presumably by a polymerization process. The effect of iron appears to be specific. Fairly large amounts of zinc chloride cause no polymerization, as is shown by the following data:

Test No.	Description	Gum (mg./100 ml.)
38A	Cracked oil, method as described	53.1
48B	Same, with 0.5 g. zinc acetate added	54.9
48C	Same, with 0.5 g. ferric chloride added	109.4

Filtercel is added to the precipitation cylinder to keep the flocculated gum from coalescing into a lumpy mass difficult to wash free of oil.

The filter tube described is the result of many experiments with filtering techniques. Other forms of filter, such as Gooch crucibles, have been more difficult to operate or have given poor results. The flocculated gum is very fine, and a careful filtration is necessary to hold all of it on the filter.

The hexane used in these tests is a technical material. It is important that the hexane contain not more than 2 to 3 per cent of aromatics. It must also be free of gum and heavy ends.

The time specified to flocculate the gum and carry out the filtration and washing steps is believed to be the optimum; it is long enough to precipitate the gum and short enough to avoid appreciable resin polymerization. Prolonged contact of the oil with acid gives slightly higher gum values.

Although the test procedure is somewhat laborious, it has been found that five or six determinations can be carried out simultaneously by one operator.

Experimental

Using the above technique, typical gum values were obtained on a number of commercial diesel fuels. The results obtained are presented in

(Continued on Page 238)

TABLE 1—TESTS ON COMMERCIAL DIESEL FUELS

Code No.	4418	4420	4421	4422	4425	4426	4400
Gravity, °A.P.I.	36.3	41.5	35.6	38.0	33.7	29.9	27.8
Vis., S.S.U. at 100° F.	41.0	38.5	32.2	32.6	43.9	42.9	38.8
Color, N.P.A.	5-6	1	2½-3	1-1½	2	3-3½	Black
Carbon res., wt. per cent	0.01	0	0	0	0.02	0.01	0.05
Aniline pt., °F.	180	181	128	162	137	161	120
A.S.T.M. Distillation—							
I.B.P., °F.	188	426	360	368	420	358	380
10 per cent at °F.	438	484	406	422	476	476	478
50 per cent	576	548	458	494	564	578	555
90 per cent		594	592	576	720	690	656
Max. B.P., °F.	710	626	584	618	744	728	709
U.O.P. factor	12.00	12.26	11.48	11.79	11.77	11.55	11.31
Diesel index	65.3	75.2	46.5	61.6	54.7	48.2	33.4
Gum content, mgs./100 ml.	22.3	5.1	27.7	6.5	6.0	79.5	76.0

TABLE 2—EFFECT OF AGING ON GUM CONTENT

Fuel—	Acid treatment, lb. 75% acid/bbl.	Acid flocculation gum—Mgs./100 Ml. Init.	20 hrs. 200° F.	8 Mo. 90° F.	9 Mo. 90° F.	13 Mo. 90° F.	20 Mo. 90° F.
1. MC virgin gas oil	None	3.6	..	..	..	..	8.4
2. Blended fuel—							
50% virgin	None	(4-5)					
50% therm. ckd.	3.0-Rerun	..	..	..	..	14.7	..
3. Thermally cracked	None	2.3	..	..	39.4	..	..
4. Thermally cracked	3.0-Clayed	3.2	3.2	..	7.0	..	..
5. Thermally cracked	5.0-Clayed	3.2	3.4	..	7.4	..	..
6. Lt. catalytic cycle	None	*10.1	14.5	..	..	20.1	..
7. Lt. catalytic cycle	1.5-Rerun	1.8	2.2	3.7	..	..	..
8. Lt. catalytic cycle	3.0-Rerun	2.1	2.5	3.1	..	..	..
9. Heavy catalytic cycle	None	*10.4	61.8	..	..	62.1	..
10. Heavy catalytic cycle	1.5-Rerun	4.6	24.5	23.2	..	..	..
11. Heavy catalytic cycle	3.0-Rerun	2.8	11.1	11.5	..	..	..
12. Heavy catalytic cycle	5.0-Rerun	2.5	6.6	6.5	..	..	..

*Aged in barrels about 6 weeks before initial gum was determined.

Training Operators for Refinery Efficiency

by J. B. Hamblen* and W. A. Sullender†

IN an industrial unit as complex as a large modern refinery, many factors contribute to efficient operation. Certainly the equipment must be designed correctly, built strongly and accurately, and maintained in good working order. For each individual unit the proper raw materials must be selected, the best operating conditions determined, and the most value realized from the final products. When all this has been done or provided for, the charge tanks are full and the rundown tanks are empty. From this point on efficiency is in the hands of the operators who get the material from the charge tanks into the rundown tanks. With the large complex modern units, this requires a lot of doing. Good operators must know how the equipment works, what factors control the process, and what adjustments to make to keep the process going smoothly and continuously. Because the materials handled are highly inflammable, safe practices must be understood and diligently followed. All this requires either long experience or thorough and intensive training.

The methods employed in training operators at the Texas City, Tex., refinery of Pan American Refining Corp. will be of interest to those who contemplate similar instruction courses. The Texas City refinery is one of the largest new refineries in the country and expansion has been rapid. Starting just before the outbreak of war and immediately thereafter, the construction of new units approximately doubled the requirements for operators. The loss of trained personnel to the armed forces added to the number of new men who had to be trained. Even the older operators who remained had to be instructed in the operation of the new units which employed equipment and processes new to the industry.

Any training program will be successful only if the people taking the training want to know more about the subject. The greater the interest, the more successful the course of instruction. When more information means a better job or more security in the same job, interest is likely to be keen. It is possible further to stimulate interest by choice of teaching methods and by a judicious preparatory sales program. However, it is essential that the customers want the information before the instruction is started. The training program which has been carried out at Pan American had the advantage that the men were eager to know more about the subject. All were either being upgraded or were being transferred to the newest in refining processes. The courses of instruction were planned to stimulate interest and to present the most useful information.

*Department head; †assistant department head, catalytic and distillation department, Pan American Refining Corp.

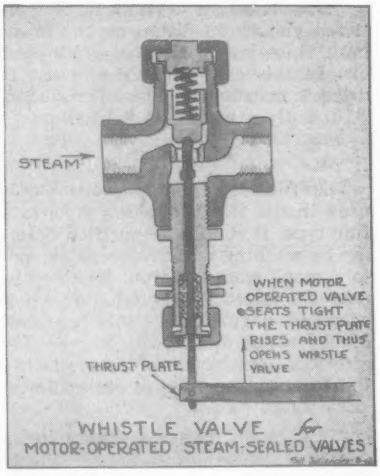
STEAM
WHEN MOTOR OPERATED VALVE SEATS TIGHT THE THRUST PLATE RISES AND THUS OPENS WHISTLE VALVE
THRUST PLATE
WHISTLE VALVE for MOTOR-OPERATED STEAM-SEALED VALVES

Fig. 1

What, Why and How

In each case the program was started with an explanation of the process —"what is to be done, why it is to be done, and how it is to be done." The source, composition, and properties of the raw materials, and the properties and function of the catalyst were studied. The composition and the properties of the final products were discussed. The effects of operating variables on product quality and yields were presented in a general way. It was found that this information was welcomed and subsequently was used to advantage, even though few had studied chemistry or general science and most had educations of high school or less.

The equipment and its operation was studied in detail, with attention to safe and efficient control of the process. General flow diagrams were

Fig. 2

Fig. 3

Fig. 4

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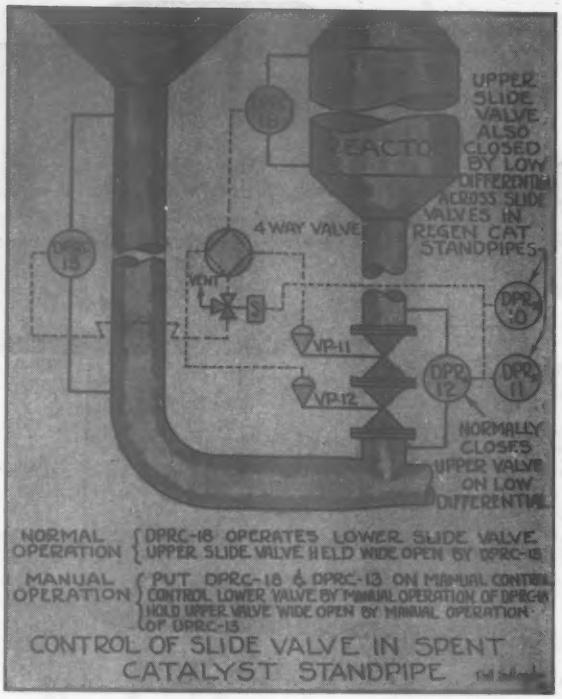
put on the blackboard and detailed diagrams of each system were prepared for distribution. As each system was studied, attention was given to individual pieces of equipment used in the system and cutaway views (Fig. 1), colored diagrams and written explanation were distributed for insertion in loose-leaf folders for each individual. Even cartoons were drawn and used where some point in operation or safety could best be illustrated with a little humor (Figs. 2, 3, 4). Special equipment such as valves, pumps, compressors, and instruments were shown in sketches and their operation was explained. For example, Fig. 5 is an instrument-control-system diagram for slide-valve operation on a catalytic-cracking unit. Such sketches were posted on the control boards during initial operations.


UPPER SLIDE VALVE ALSO CLOSED BY LOW DIFFERENTIAL ACROSS SLIDE VALVES IN REGEN CAT STANDPIPES
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4 WAY VALVE
VENT
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VP-12
DPRC 18
DPRC 13
DPR 10
DPR 12
DPR 11
NORMALLY CLOSED UPPER VALVE ON LOW DIFFERENTIAL
NORMAL OPERATION
DPRC-18 OPERATES LOWER SLIDE VALVE
UPPER SLIDE VALVE HELD WIDE OPEN BY DPRC-13
MANUAL OPERATION
PUT DPRC-18 & DPRC-13 ON MANUAL CONTROL
CONTROL LOWER VALVE BY MANUAL OPERATION OF DPRC-18
HOLD UPPER VALVE WIDE OPEN BY MANUAL OPERATION OF DPRC-13
CONTROL OF SLIDE VALVE IN SPENT CATALYST STANDPIPE

Fig. 5

Lectures and question-and-answer sessions were relieved by trips to the unit to see the equipment being studied. As flow diagrams were worked out on the board, the lines and other equipment were followed in the field to associate the actual equipment with the information being presented in the classes. The field inspections were made in groups of two or three and no field talks or guided trips were made. Each group worked out the system for itself and asked questions upon reassembly.

The training was finished by going over the previously prepared starting instructions, operating instructions, and shutting-down instructions. Frequently these were changed or supplemented by points brought out in the discussions. It has been found that the operators preserve the notes, drawings, and diagrams collected in these courses of instruction and make use of them in teaching new men who come into the organization later. The training courses have proved their value in producing operators who know how to run the units safely, efficiently, and smoothly during normal operations and who are alert, confident, and resourceful in times of emergency.

Acid Flocculation Test

(Continued from Page 235)

Table 1. These stocks were purchased samples of oils sold in 1941-1942 as diesel fuels. They cover a wide range of materials representative of those used in high-speed automotive as well as low-speed stationary diesel service. The samples were fairly typical of current diesel fuel sales and include products from a variety of companies and areas. The samples were about 3 months old when analyzed.

In Table 2 is presented a summary of data showing the effect of aging, in both accelerated and extended aging tests, on a number of refinery stocks. The accelerated tests were carried out in a constant temperature oven at 200° F. using 100 ml. of the fuel in a 250-cc. lipped, glass-stoppered Erlenmeyer flask, in which the gum could be flocculated later without transferring the oil. The aging tests at 90° F. were carried out in vented quart glass bottles, starting with about 800 ml. of oil. Some of the oils formed a flocculent precipitate in both the accelerated and long-time aging tests. This precipitate was determined separately and is not included in the figures shown in the table.

Fuel 3, an untreated thermally cracked stock, is unstable. The aged fuel is known to give poor performance in both diesel engines and domestic burners, because of excessive gum deposits. Fuel 1 and 2, stable in storage, are known to be satisfactory in that they have a negligible tendency to form gum in the fuel systems of diesel engines or domestic burners.

Validity of the Test

Because the test was recently developed, no opportunity has been afforded as yet for extensive correlation with actual service performance in the various types of equipment in which heavier distillate fuels are used. The results appear rational, however, in that straightrun stocks, such as kerosene, known to be stable in storage show a very small increase in acid flocculation gum content in extended storage tests. Untreated thermally or catalytically cracked stocks show appreciable increase in gum content during relatively short periods in storage. Furthermore, the test is independent of the volatility of the fuel, as is indicated by data in Table 1 on the field samples of typical diesel fuels. Reproducibility was found to be good provided the prescribed technique for carrying out the test is closely adhered to. Careful duplicate analyses on high-gum stocks give results differing by about 2 per cent in total gum content—a deviation of 0.8 mg. in 40 mg. total gum. An average deviation of 5 per cent should be readily obtained.

The proposed test is regarded as a suitable method for distinguishing between gum and the hydrocarbons of low volatility present in diesel or distillate fuel oils. It is believed that such a method is the initial step in studying the gum problem and is highly desirable for determining the real effects of aging on field performance of these fuels.

Acknowledgment

The authors wish to express appreciation to R. L. Rittschof and A. J. Steinbach for extensive data obtained in checking the accuracy and validity of the method.

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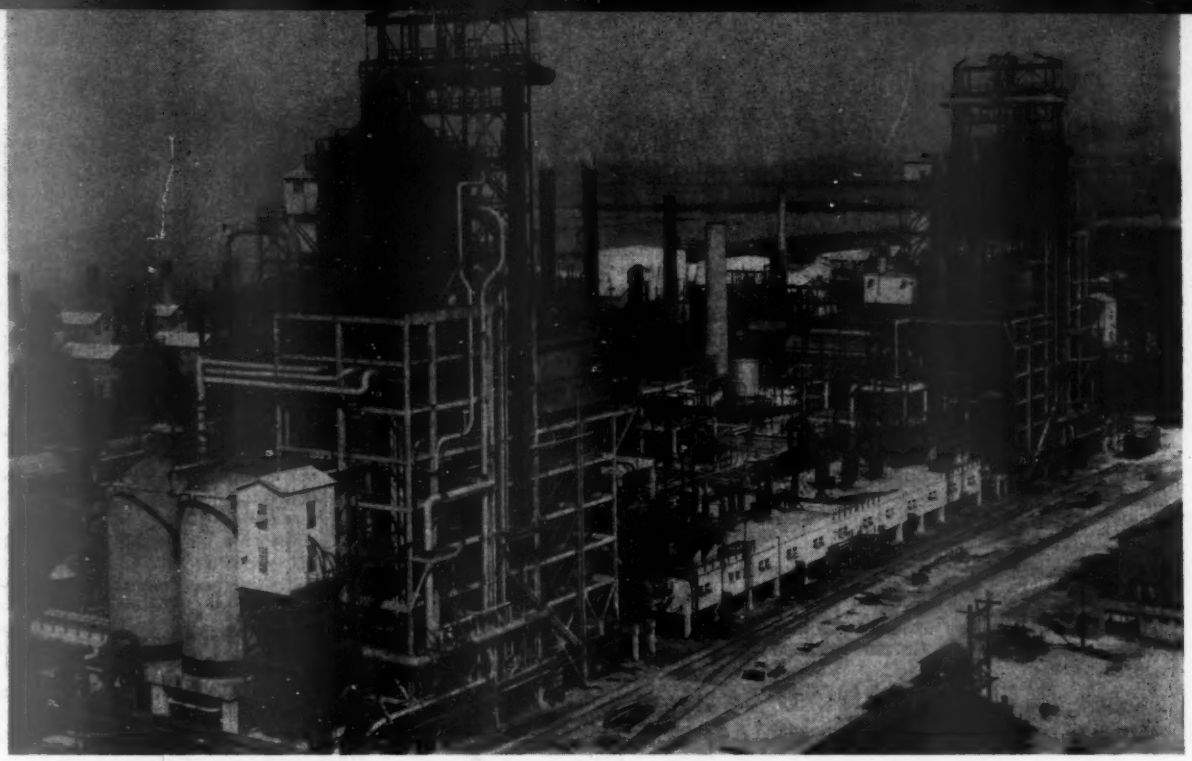
R. E. King has been transferred from the New Orleans office of The Texas Co. to Jackson, Miss., to succeed **Dick Priddy** who has resigned as geologist for the company to teach chemistry and geology at Millsaps College in Jackson.

Charles S. Agey has become geologist in charge of the Wichita, Kans., office of Amerada Petroleum Corp. following his release from the service.



Fluid catalytic cracking units Nos. 1 and 2, at The Texas Co.'s Port Arthur, Tex., refinery, maintenance of which is discussed in this article

Fluid Catalytic Cracking Units Present Complex Problems in Maintenance

THE Texas Co. has in operation four fluid catalytic cracking units, the first of which has been in operation since March 1944. Experience in connection with the operation and turnaround of these units has demonstrated the necessity and justification for thorough study and careful attention to the maintenance problems of this particular type of equipment. High on-stream time is of major importance on these units because of the loss of high octane gasoline blending components occasioned when shutdowns are necessary, the high cost of turning the units around, and the large labor requirements.

Peculiarities of Maintenance

The maintenance of fluid catalytic cracking units presents different problems from other types of units because of the fluid flow of large amounts of catalyst with resulting erosion, the high temperatures experienced during regeneration and the large size of lines necessitated by the low pressure and high catalyst flow rates.

Many installations of the same general design of fluid catalytic cracking units were made at approximately the same time. The step from pilot plant units to large scale fluid catalytic cracking units was made over a short period of time so that it was not possible to modify the design to eliminate points of weakness which show up on commercial scale installations.

The major difficulties encountered on fluid catalytic cracking units may be classified as follows:

(1) Erosion; (2) temperatures in excess of design due to failure of internal insulation; (3) plugging and coking; (4) mechanical equipment difficulties.

Erosion

Erosion is known to be a function of velocity, catalyst concentration, angle of impingement and probably of catalyst shape and abrasiveness. Eddy currents set up by flow obstructions, line shape and position and extraneous entering streams may result in an abnormally high number or velocity of impacts and localized erosion. Attempts have been made to predict or explain points of high erosion by visual observation of catalyst flow in small glass reproductions of the commercial line systems. General indications resulted but were inconclusive because of wall effect.

The points of excessive line erosion may be grouped as follows:

1. Those resulting from use of short radius bends: (a) reactor inlet lines; (b) recycle catalyst carrier lines; (c) air-catalyst distributing spider in regenerator; (d) flux and dilution catalyst carrying lines.

2. Those resulting from eddy currents or interference with catalyst flow by fixed obstructions or divergent streams: (a) sloped straight section of reactor inlet lines; (b) oil injection points on reactor inlet lines; (c) thermowells and guards; (d) carrier air injection points and line below standpipe; (e) lap rings on internally insulated pipe; (f) piping adjacent to sprays in regenerator overhead lines and waste heat cooler outlet ducts.

Corrective steps taken or under consideration are as follows:

1. Replacement of short radius miter bends with long radius smooth bends.

2. Provision of wear plates, particularly in carrier lines below standpipes.

3. Employment of material more resistant to erosion.

4. Provision of fluffing lines in bottom of horizontal section of lines to

prevent catalyst dropping out and causing high velocity in the upper horizontal section and entering the bend.

5. Elimination of auxiliary nozzles and thermowells in lines wherever possible.

6. Provision of distributor plates to obtain uniform carrier air flow in place of jet effect originally obtained.

7. Provision of buffer strips ahead of lap ring welds.

Erosion has also been a problem on the following equipment: slide valves, cyclones, and reactor shell, however, problems in connection with these items are deemed too lengthy to include in this article.

Temperatures in Excess of Design Resulting from Failure of Internal Insulation

The catalyst carrying line systems on the regenerator side of the Port Arthur units were internally insulated and provided with an internal metal liner. The pressure wall and the expansion joints and bends were designed on the basis of reduction in flowing temperature through the internal insulation.

No provision was made in the original internally insulated pipe design for vapor stops to prevent flow of catalyst and vapor back of the liner and against the pressure pipe wall. Flow of catalyst and vapor back of the liner was found to occur to an excessive extent due to the following:

1. Erosion of the lap rings covering the space between adjacent sections of lining in carrier lines.

2. Flow of catalyst back of the liners on standpipes by improper installation of aeration nipples.

Loss of insulation and high pipe wall temperatures resulted.

Severe erosion of the pipe wall resulted from flow of catalyst back of the liner on the horizontal and bend portion of catalyst carrier lines. Bowing and corrugation of standpipes resulted from the high wall temperature described above.

The internal insulation on the spent catalyst carrier line has been redesigned to incorporate the following improvements: (a) vapor stops at every panel to prevent flow of catalyst back of the liner; (b) provision of wear plates over the liner in the bend section; (c) provision of buffer strips ahead of the lap ring welds to prevent erosion and failure of the lap rings.

Vapor stops have been installed at some locations and modifications made to prevent aeration air flow back of the liners on the internally insulated standpipes.

The original internally insulated recycle catalyst standpipes on the Port Arthur units have been replaced with unlined pipe. Further replacement of internally insulated pipe with unlined pipe will depend on the performance of the improved internally insulated pipe described above.

On The Texas Co. Los Angeles and Lockport units, no internally insulated pipe was used. All lines on the regenerator side were fabricated of unlined carbon steel. So far, the only difficulty due to use of unlined pipe has been sagging of a section of the regenerator overhead lines.

Plugging and Coking of Equipment

The original installation of spray nozzles for normal cooling in the dilute phase of the regenerator consisted of 72 small nozzles uniformly spaced over the cross-sectional area of the regenerator. Experience indicated as high as 80 per cent of these nozzles would be plugged on shutting down. Extensive failure of internal piping feeding these nozzles has also been experienced on one of the units.

This original arrangement was abandoned in favor of provision of six replaceable spray nozzles introduced around the periphery of the regenerator a few feet above the normal bed level.

Coking of the bottom of the fractionator tower was an early problem in the Port Arthur units. Sprays were originally installed to provide a liquid wash below the bottom baffles. Large pot strainers were provided to prevent coke formed in the tower from fouling the slurry pumps and

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the slurry exchanger and boilers. Squirrel cage type strainers of large mesh were installed in the tower above each of the suction lines to prevent large pieces of coke from entering and plugging the suction lines.

The elimination of the internal extension of the vapor lines and the provision of slurry wash for the shell below the bottom disc baffles have eliminated fractionator coking difficulties.

Mechanical Equipment Difficulties

1. **Precipitators.**—Leakage of precipitators on the Port Arthur units has been a major problem. Leaks have occurred mainly at the junction of the shell to the hoppers. In practically all cases, these leaks were inaccessible. Steps have been taken during operation to minimize the leakage by venting catalyst and gas through a pipe equipped with a valve and shooting gunite around the leaking area. It has been found necessary to reweld a considerable portion of the seams of the precipitators.

Leakage at precipitator manways originally experienced at Port Arthur was prevented on the Los Angeles units by utilization of double the normal number of hold-down bolts and provision of the backing up ring for support of the packing angle.

2. **Recycle catalyst cooler and waste heat boilers.** — Erosion of the upper cone of the recycle catalyst cooler had been severe on the Los Angeles unit until steps were taken to relocate the cone section 18 in. farther from the tube sheets to reduce the velocity of the catalyst stream impinging on this cone.

Erosion of the waste heat boiler inlet tubes has also been experienced. Corrective steps taken have consisted of providing extended ferrules and rewelding of tubes which have pulled loose from tube sheets.

3. **Blower and turbine failures.**—On the Port Arthur units, two main air blower turbine failures occurred due to thrust bearing failures. These failures could have been due to excessive water in the steam, contaminated lube oil or excessively high oil temperatures, or a combination of these.

The following corrective steps have been taken: (a) install steam separators in steam lines from waste heat boilers; (b) reroute all steam through superheater; (c) install additional steam traps in steam system and provide sight glasses on individual steam separators of each of the blower turbines; (d) provide clarifier, filters, auxiliary oil pumps and low oil pressure alarm on each blower turbine.

Procedure for Handling Turnaround of Fluid Catalytic Cracking Units

The following steps are taken in anticipation of a turnaround of one of the Fluid catalytic cracking units:

1. Prepare work list, including inspection, repair, maintenance and change items. This work list includes items picked up by operators and maintenance department during operation, inspection and repair items anticipated basis operation of unit or experience factors from previous turnaround and change items which have been agreed upon in advance of the shutdown.

2. Labor requirements are estimated on the basis of the work list and steps taken to procure same.

3. A review is made well in advance of the shutdown of material requirements and necessary steps are taken to procure same. Spare parts are, of course, kept stocked to handle breakdown or repair to equipment during operation of the unit.

4. As much material as possible is prefabricated in advance of the unit shutdown.

5. Shortly before the unit comes down, items requiring attention are tagged and steps are taken to assemble such material as possible at the site where it will be required.

When the unit is brought down and opened up, cleaning of catalyst is scheduled so as to permit rapid inspection of those points in the unit where major repairs or changes are required. Provision has been added for numerous additional manways and nozzles for cables.

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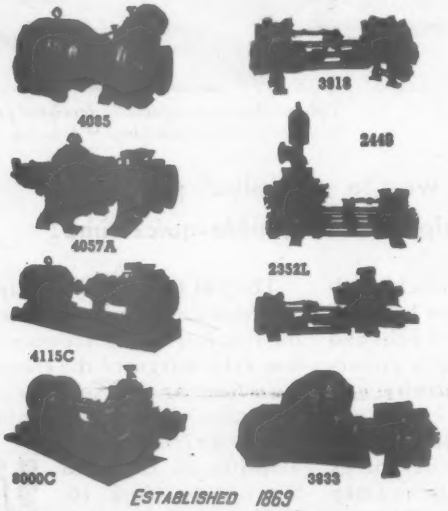

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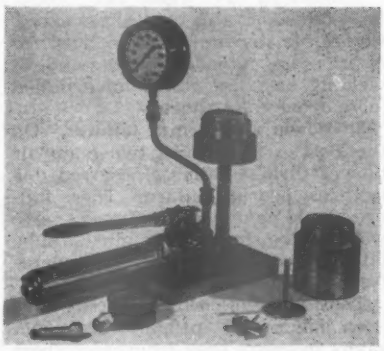

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Application of Fluid Catalytic Cracking In Present Refinery Operations

*by Davis Read**

DURING the present period of reconversion to peacetime operations many refiners are making detailed studies of the processes recently developed to produce improved motor fuels. These studies have shown that catalytic cracking is the most generally applicable new process and that catalytic polymerization of propylene and butylenes from the cracking operation is a profitable supplementary process.

The simplifications and improvements which have been made in the design of a fluid catalytic-cracking unit[1] have resulted in sufficiently low investment and operating costs to permit this process to compare favorably with thermal-cracking investment and operating costs. It appears that the average refiner considering a program of expansion can now justify the installation of fluid catalytic-cracking equipment primarily on the basis of lead savings, as compared with the installation of a new two-coil thermal-cracking unit to process the same amount of charging stock.

In the modernization of a refinery containing existing thermal-cracking equipment the installation of only the catalyst section of the fluid catalytic unit, with the use of the existing feed preparation, fractionation, and gas-recovery equipment is advantageous for some refiners. In other cases, in which the economics justify operation of the thermal-cracking unit, it is necessary to install complete facilities for catalytic cracking.

Because of the many variations in market requirements, crude properties, and refining facilities, it is not possible to make general statements or to work out a typical economic study which will apply to all refiners considering the installation of catalytic-cracking equipment. A detailed study must be made of the operation of each refinery in order to determine the most desirable capacity and the most profitable method of operation to establish a basis for the design. However, the factors involved in the installation of fluid catalytic cracking in a refinery that contains existing thermal-cracking facilities can be illustrated by discussion of an example based on assumed average conditions.

The accompanying tables show the results of such a study, which is based on a typical refinery processing 5,000 bbl. per calendar day of Mid-Continent crude oil. It was assumed that the present facilities of this refinery would include crude distillation, thermal cracking, catalytic polymerization, and treating equipment. To meet the present market demands the average refiner in the Mid-Continent area is using virtually the maximum amount of tetraethyl lead in both premium and housebrand gasoline while producing the maximum amount of kerosene and burner oils. A number of refineries are equipped to produce and market special solvents from low-octane naphthas, but the majority utilize the naphtha in third-grade gasoline or tractor distillates. Similarly, some refiners in this area are presently producing asphalt, but in the average case the heavy fraction of the crude is cracked thermally. This example was therefore worked out on the basis of producing the three grades of gasoline, kerosene, and Nos. 1, 2, and 6 fuel oil. The average market prices for these products were taken from the February 18, 1946, quotation of Platt's Oilgram.

It probably would not be profitable, under present market conditions, to operate the thermal unit to crack the total cycle stock produced from a fluid catalytic-cracking unit. This is due to the fact that over 70 per cent of the cycle oil is normally light enough to meet the 90 per cent dis-

Nearly 50 per cent of a Mid-Continent crude may be converted to motor gasoline, made into three grades by the combination of catalytic cracking, polymerization, and crude topping, according to the values given in this article. Either two grades—premium and housebrand—or these two with a third grade fuel may be made. Twenty-five per cent of the production can be premium of 85 A.S.T.M. octane number, with 75 per cent housebrand at 80 O.N. Operating costs for a 5,000-bbl.-per-day plant of this type will be about $1,788 per stream day. Maximum yields of Nos. 1, 2, and 6 fuel oils are produced, the distillate oils being especially in market demand now.

TABLE 1—YIELD STATEMENT

	B/CD	Vol. %
Crude distillation:		
Mid-Continent crude oil	5,000	100.0
Straightrun gasoline	850	17.0
Naphtha	250	5.0
Kerosene	500	10.0
Intermediate distillates	950	19.0
Reduced crude	2,400	48.0
Loss	50	1.0
Vacuum flashing:		
Reduced crude charge	2,400	100.0
Gas oil	2,000	83.2
Crude residue	400	16.8
Catalytic cracking and polymerization:		
Gas oil charge	2,255	100.0
Debutanized gasoline	1,121	49.7
Debutanized polymer	110	4.9
Butanes after polymerization	101	4.5
Light cycle stock	631	28.0
Heavy cycle stock	271	12.0
Total fuel gas, MM B.t.u./day	596	....

TABLE 2—GASOLINE SUMMARY

Total Gasoline Blend

	B/CD	Reid vapor press.	MM octane: Clear	MM octane: Plus 3.0 cc. TEL/gal.
Light straightrun	850	11.0	61	80
Naphtha	250	1.0	52	70
Debutanized catalytically cracked	1,121	5.5	*86	*88
Debutanized polymer	110	2.2		
Butanes	101	68	95	100
Total	2,432	10	74.3	83.8

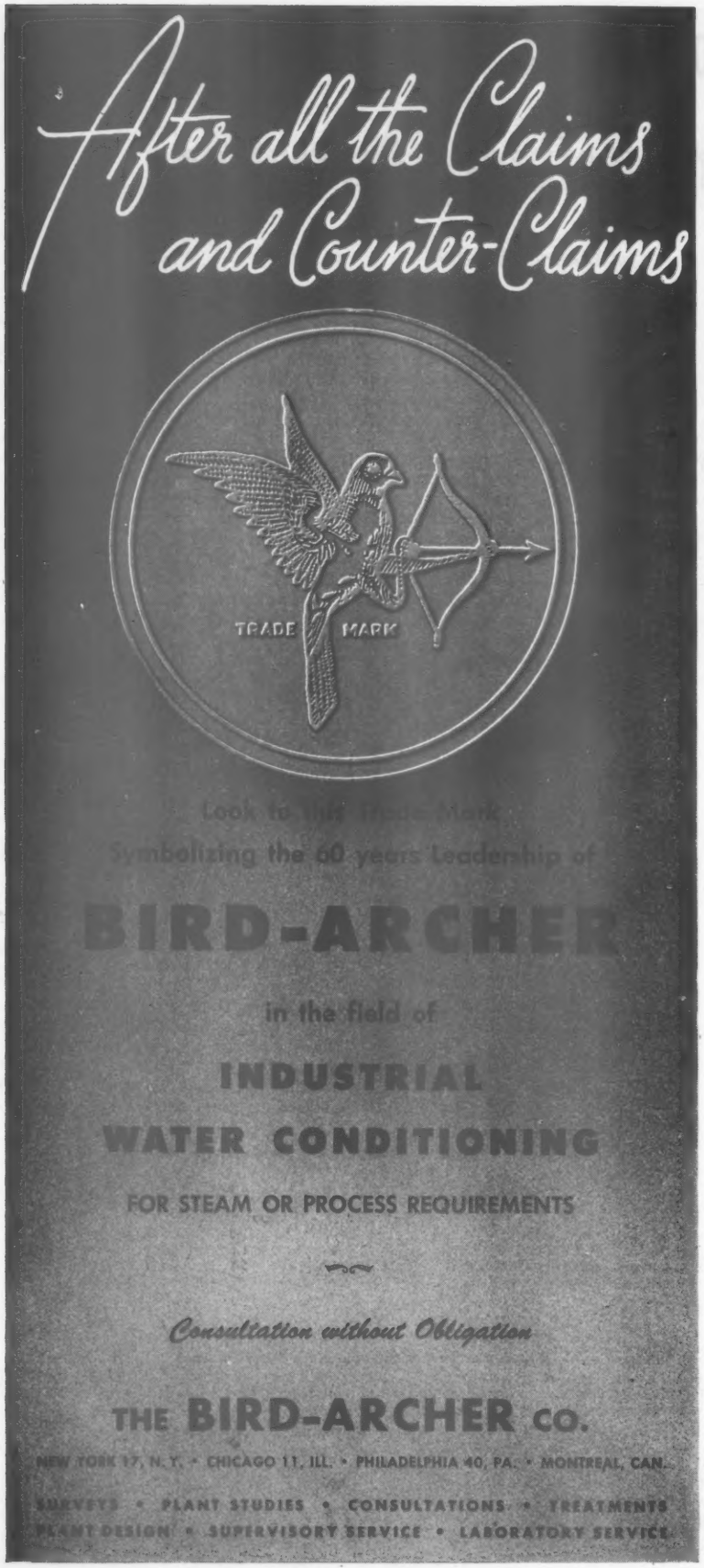
Gasoline Production and Lead Requirements

Oct. No. and per cent of premium	90 (25%)	80 (50%)	81 (25%)	85 (25%)
Oct. No. and per cent of housebrand	75 (65%)	75 (50%)	76 (65%)	80 (75%)
Oct. No. and per cent of third grade	66 (10%)	..	67 (10%)	..

	B/CD	cc. TEL/gal.	B/CD	cc. TEL/gal.	B/CD	cc. TEL/gal.	B/CD	cc. TEL/gal.
Premium gasoline	608		1,216		608		608	
Housebrand gasoline	1,581		1,216		1,581		1,824	
Third grade gasoline	243		....		243		....	
Total	2,432	0.2	2,432	0.5	2,432	0.3	2,432	1.8

*Blending value (estimated).

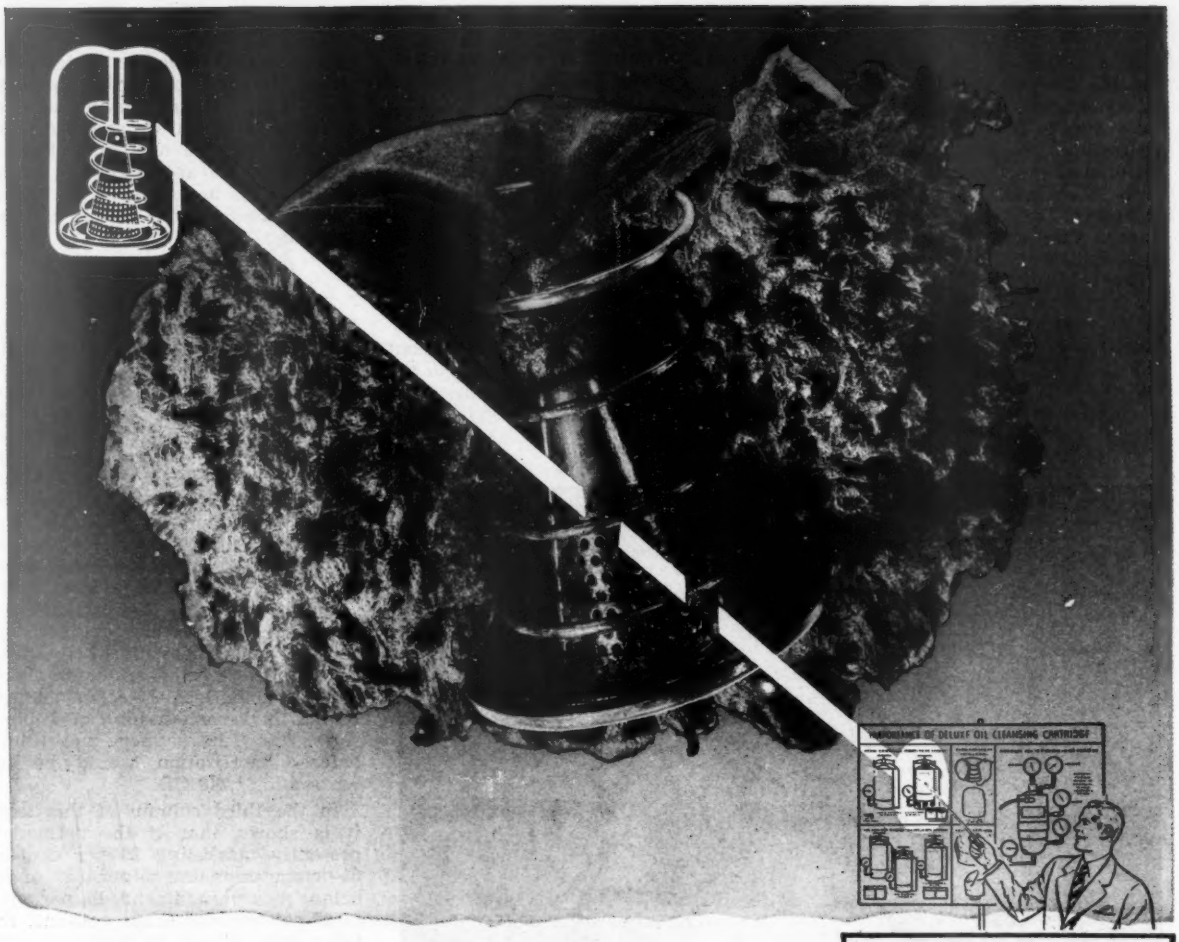
*Universal Oil Products Co.



tillation specification of A.S.T.M. No. 2 fuel oil, and could be sold as such after blending with kerosene or other light distillates to meet the 10 per cent distillation specification. When producing 400-end point catalytic gasoline, the 10 per cent distillation temperature of the corresponding light cycle oil may exceed the 440° F. specification slightly so that it is necessary to blend some kerosene with the light cycle stock to produce No. 2 fuel oil. It is assumed that 15 per cent kerosene would be blended with the light cycle stock to produce No. 2 fuel oil in the average case. In addition, it is assumed that the thermal-cracking unit would be shutdown at the present time and the crude bottoms would be blended with the heavier fraction of the catalytic cycle oil and sold as No. 6 fuel oil. Table 1 shows typical yields which might be expected under the conditions selected for this example. The reduced crude, representing 48 per cent of the Mid-Continent crude oil, is charged to a vacuum unit. The average Mid-Continent crude oil contains about 8 per cent asphalt bottoms so that the production of vacuum gas oil has been set at 2,000 bbl. per calendar day. The once-through capacity of the catalytic-cracking unit at 60 per cent conversion has been arbitrarily set at 2,400 bbl. per stream day, or 2,255 bbl. per calendar day, assuming that 255 bbl. per calendar day of gas oil from the crude unit would be available for cracking.

Blending Value of Gasoline

The production rates and properties of the various gasoline streams produced are given in Table 2. Under these conditions the total gasoline blend containing all of the naphtha and light straightrun gasoline requires less than 0.1 cc. per gal. to reach 75 M.M. octane rating. Even with the catalytic polymerization of the recovered C_3-C_4 unsaturates sufficient butanes are available to blend all of the gasoline produced to 10-lb. R.v.p. Note that the catalytically cracked and polymer gasoline has an estimated M.M. blending value of 86-88 in the mixture with these straightrun fractions. The blending value of the catalytically cracked gasoline varies with its concentration in the blend, with even higher blending values being realized as the concentration of the straightrun fractions is increased. The unleaded 10-lb. R.v.p. catalytically cracked gasoline has an actual M.M. octane rating of 80. The estimated Research Method blending value of the catalytically cracked plus polymer gasoline in this mixture would be 100 without lead, and 103 with 3 cc. TEL/gal. The lead requirements for the production of various proportions of the three grades of gasoline at varying octane levels are also included in this table.



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A summary of the operating costs for the various sections of the refinery is given in Table 3. These unit costs were estimated to include supervising and operating labor, utilities, maintenance, laboratory testing, catalyst, chemicals, royalties, taxes and insurance, for each section of the refinery. The over-all refinery overhead and administration cost has been estimated at 7 cents per barrel of crude and included as a separate item in the operating costs. The estimated investment cost of somewhat less than a million dollars includes a new vacuum flashing unit, the fluid catalytic-cracking unit complete with new fractionating and gas-recovery equipment to produce a liquid C_3-C_4 feed to the polymerization unit, and additions to the present polymerization unit to permit it to handle the increased C_3 and C_4 fractions produced. This total cost does not include auxiliaries, such as tankage, which are assumed to be adequate for the new unit. The investment cost can, of course, be reduced when it is possible to utilize existing parts of the present refining facilities.

TABLE 3—SUMMARY OF OPERATING COSTS

	$/bbl.	Bbl./CD	$/CD
Crude distillation	0.08	5,000	400
Vacuum flashing	0.08	2,400	192
Fluid catalytic cracking and gas recovery	0.31	2,255	699
Polymerization	1.14	110	125
Caustic washing and inhibitor	0.02	1,121	22
Refinery overhead and administration	0.07	5,000	350
Total			1,788

Costs and Returns

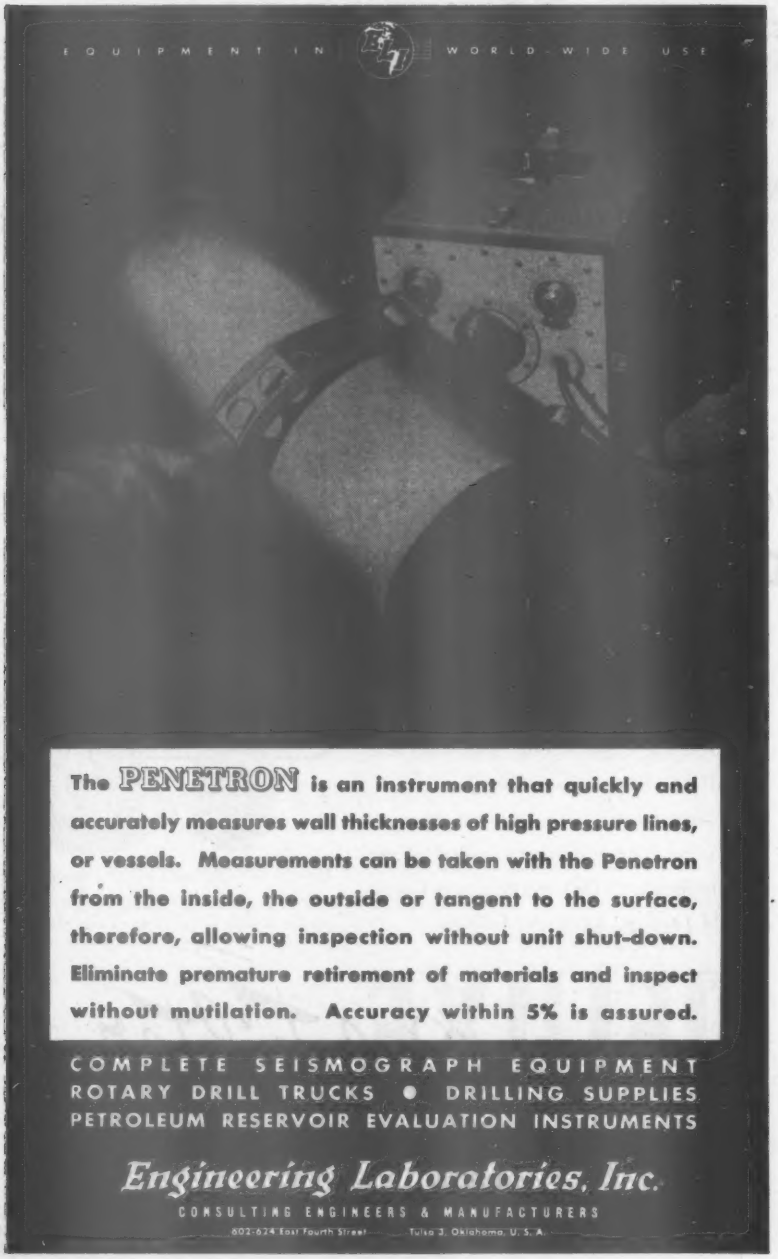
The costs and returns which would be realized at the market prices and yields set for the example are given in Table 4. Assuming an average present production of 25 per cent of 80-octane premium, 65 per cent of 75-octane housebrand, and 10 per cent of 66-octane third-grade gasoline, the refinery would realize a net return before amortization of $1,000/CD, as shown in the first column of this table. This net return does not make allowance for depreciation of present equipment, interest on investment or income tax.

If it is desired to eliminate the production of third-grade gasoline and sell, for example, half of the total gasoline as 80-octane premium, with the remainder as 75-octane housebrand, the second column of Table 3 shows that the refinery net return before amortization would be increased to $1,240/CD.

In the third column of this table it is shown that if the refiner is presently marketing 25 per cent of 81-octane premium, 65 per cent of 76-octane housebrand, and 10 per cent of 67-octane third-grade gasoline, the net return would be $982/CD with catalytic cracking.

As insurance against possible future competition to increase the octane ratings still further, the last column of this table shows that the refiner could produce 25 per cent of 85-M.M. octane premium and 75 per cent of 80-octane housebrand without decreasing the total volume of gasoline produced and without exceeding present maximum TEL concentrations. However, the production of this high-grade gasoline with no change in price structure or volume of gasoline produced decreases profit to $745/CD, largely because of increased lead requirements.

While this example has been based entirely on catalytically cracking the liquid gas oil fraction at 900° F. and 60 per cent conversion in once-through operation, it is possible to carry out many other operations in this same unit, depending on the quality and quantity of the products desired. The flexibility of the fluid catalytic-cracking process permits a given unit to handle a wide range of feed stocks and to vary the proportions of gasoline, gas, and fuel oil produced to a greater extent than a corresponding thermal-cracking unit. By variations in cracking temperature or in the amount of catalyst in the reaction zone at a given raw-oil feed rate, the conversion, or gas oil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disappearance, and the proportion of gasoline and gas to fuel oil can be varied widely. Cracking temperature is controlled simply by means of the rate at which the hot catalyst from the regenerator is circulated to the reactor. An increase in the reactor temperature at constant conversion results in an improved clear octane number. The amount of catalyst in the reaction zone is varied by changing the setting on the instrument which controls the reactor level. An increase in the amount of catalyst in the reactor with a constant raw oil feed rate results in a greater conversion to gasoline and gas.

If it is desired to crack only the heavy vacuum gas oil and sell all of the intermediate distillates from the crude unit as burner oils, the decreased volume of feed to the catalytic unit could be processed in a recycle operation, with an increased gasoline yield, by recycling a portion of the liquid catalytic cycle stock to fill the unit.

As previously mentioned, it probably would not be profitable to operate the thermal-cracking equipment under present market conditions to crack the cycle stock from the catalytic unit, since this product can be sold as burner oil. With a decline in the demand for burner oil and an increased demand for gasoline, however, the intermediate distillates and kerosene, as well as the vacuum unit gas oil, could be charged to the catalytic unit at reduced conversion.

The additional cycle stock produced at low conversion could be cracked in a mixture with the crude bottoms in the existing thermal-cracking unit to produce additional gasoline. For example, the 2,400-bbl.-per-stream-day fluid catalytic-cracking unit quoted in this discussion could process approximately 3,300 bbl. per stream day of gas at 50 per cent conversion, with an increase of 15-20 per cent in the catalytic gasoline production.

Certain types of topped or reduced crude can be processed successfully in a fluid catalytic-cracking unit, thereby eliminating the necessity for special feed preparation steps. These residual stocks must be relatively free of salt and asphalt, however, to produce the best results. Several commercial fluid catalytic-cracking units are processing relatively clean reduced crude at present. The results obtained on one of these commercial units when charging a coastal topped crude directly to the reaction zone are summarized briefly in Table 5.

These data show that 37.7 per cent of 9.5-lb. R.v.p. gasoline having an 80.9-M.M. clear octane number is being produced. This high-quality gasoline is blended with straightrun to meet present octane levels with very low lead requirements. Over 40 per cent of light cycle stock is also being produced and sold as burner oil.

TABLE 5—SUMMARY OF RESULTS—FLUID CATALYTICALLY CRACKING COASTAL TOPPED CRUDE, ONCE-THROUGH OPERATION

Yield:	
Topped crude charge	100
Gasoline (9.5 lb. R.v.p.), volume per cent	37.7
Excess butanes and butylenes, volume per cent	8.8
Light cycle oil, volume per cent	43.7
Heavy cycle oil, volume per cent	6.3
Fuel gas, CF/bbl. of chg.	270

Properties of charge and products:	Topped crude charge	Gasoline	Light cycle oil	Heavy cycle oil
Gravity, °A.P.I.	28.2	57.5	29.9	22.0
Aniline point, °F.	168	...	155	...
Corrosion	...	Neg.	...	...
Doctor test	...	Neg.	...	...
Reid vapor pressure	...	9.5	...	...
Flash point, °F.	200	...	230	230+
Salt, lb./1,000 bbl.	2-5	...	...	...
Conradson carbon, wt. %	0.8	...	...	...
M.M. octane clear	...	80.9	...	...
+3 cc. TEL/gal.	...	88.3	...	...
100 ml. distillation:				
I.b.p., °F.	460	85	436	517
10 per cent	539	120	498	632
50 per cent	632	232	544	705
90 per cent	Cracking	390	610	792
End point, °F.	Cracking	426	670	.

Summary

While it is not possible to draw general conclusions which will apply to all individual refineries, many of the economic factors involved in considering fluid catalytic cracking as a new refinery tool to meet present and future market conditions have been illustrated by discussion of an as-

TABLE 4—COMPARATIVE ECONOMICS

Refining processes	(Existing crude distillation, polymerization, and treating new vacuum flashing and fluid catalytic cracking)									
Market conditions	Limited gasoline and maximum kerosene and fuel oil production									
Octane number and per cent of premium	80 (25%)		80 (50%)		81 (25%)		85 (25%)			
Octane number and per cent of housebrand	75 (65%)		75 (50%)		75 (65%)		80 (75%)			
Octane number and per cent of third grade	66 (10%)		None		67 (10%)		None			
Total gasoline produced, B/CD	2,432		2,432		2,432		2,432			
cc. TEL/gal. of total gasoline	0.2		0.5		0.3		1.8			
Credits:	Product c/gal.	Value $/bbl.	B/CD	$/CD	B/CD	$/CD	B/CD	$/CD	B/CD	$/CD
Premium gasoline	6.50	2.73	608	1,660	1,216	3,320	608	1,660	608	1,660
Housebrand gasoline	5.50	2.31	1,581	3,652	1,216	2,809	1,581	3,652	1,824	4,213
Third grade gasoline	5.125	2.15	243	522	None	....	243	522	None	....
Kerosene	4.375	2.05	389	797	389	797	389	797	389	797
No. 1 fuel oil	4.375	1.84	400	736	400	736	400	736	400	736
No. 2 fuel oil	4.125	1.73	1,037	1,794	1,037	1,794	1,037	1,794	1,037	1,794
No. 6 fuel oil	....	0.90	671	604	671	604	671	604	671	604
Fuel gas, M.M. B.t.u./CD	$0.10	....	598	60	598	60	598	60	598	60
Total credits	....	....	...	9,825	....	10,120	....	9,825	....	9,864
Debits:										
Crude oil	....	1.40	5,000	7,000	5,000	7,000	5,000	7,000	5,000	7,000
Operating expenses (see Table 3)	....	....	...	1,788	....	1,788	....	1,788	....	1,788
Tetraethyl lead at $0.0018/cc.	....	....	....	37	....	92	....	55	....	331
Total debits	....	....	....	8,825	....	8,880	....	8,843	....	9,119
Net returns:										
Before amortization	....	....	....	1,000	....	1,240	....	982	....	745
Amortization of new investment (10% per year of $850,000)	....	....	....	233	....	233	....	233	....	233
After amortization	....	....	....	767	....	1,007	....	749	....	512

sumed typical example. These studies may be summarized as follows:

1. Under the conditions used in this example the average smaller refiner operating a fluid catalytic-cracking unit for present markets would realize a reasonably high net return, while amortizing new equipment installed to insure adequate protection in any future competition for high-octane numbers.

2. The high blending value of the gasoline produced from a fluid catalytic-cracking unit permits both a marked reduction in the lead requirement for present octane levels and the profitable disposal of low-octane-number stranghtrun fractions.

3. The production of burner oils as a by-product of fluid catalytic-cracking gas oil and, in some cases, topped crude, is particularly advantageous for present markets.

4. The flexibility of a fluid unit permits processing many types of stocks in either once-through or recycle operation to meet changing local market conditions.

Reference

1. Anderson, N. K., and Sterba, M. J., The Oil and Gas Journal, 44, 77-80, 84-88 (1945).

Additives Impart Necessary Qualities To Lubricating Oils

ONE of the outstanding results of the remarkable developments in lubricating-oil manufacture during the war period is the greatly accelerated rate of adoption of additive-treated, heavy-duty lubricants by the oil and automotive industries. The properties found necessary in these products and the methods by which these properties were obtained and improved, have carried over inevitably into peacetime, and the lubricants used to keep Army trucks moving are being supplied to peacetime vehicles for the same purpose. These products are more expensive than those supplied prewar, but they also do a much better job, say refiners and automotive builders alike. In fact these enhanced properties are necessary to the most successful operation of present equipment and that which will in future come off the assembly line.

Consequently additive-treated oils are being marketed more widely than ever before. This is especially true in the East, and Pacific and Gulf Coasts, with the Mid-Continent and central areas trailing closely behind if trailing at all. Practically every major refiner-marketer in these areas is supplying oils containing one or more addition agents to improve the service performance of the oil. More often these oils contain oxidation inhibitors only to retard formation of corrosive and other oxidation products damaging to the oil and the engine. In a number of cases the oils contain both inhibitors and detergent-dispersant additives, especially for oils destined for extreme operating conditions in industrial and commercial services. And this trend is accelerating rapidly.

Excepting truck - bus - tractor and similar types of operation this trend is not forced especially by the demanding needs of the engines lubricated, although this may be true in the reasonably near future, with the advent of postwar motor cars. Whatever the moving cause, competition between marketers for increased sales on the one hand, of automotive equipment operators to get the most out of existing equipment on the other, are speeding up the adoption of these oils in the making of which we are war-educated. New automotive engines of every type are expected to accentuate the trend.

Prior to the war several refiners introduced additive-treated oils, in some cases the so-called "heavy duty" oils containing both inhibitors and detergent dispersants sometimes being sold for both truck gasoline and diesel engines and for passenger cars. By an extended train of events the Society of Automotive Engineers, the American Petroleum Institute, and the military forces developed an all-purpose oil under successive specifications 2-104, 2-104A, and 2-104B, and scores of oils were supplied under these specifications. Through a series of meetings these technical bodies devised definitions for three grades of oils which are considered suitable for the several peacetime services. These grades are known as "regular," "premium" and "heavy-duty" oils.

The regular grade is defined as a straight mineral without additive of any kind, suitable for engines operating under moderate conditions. The premium grade is one having proved oxidation stability and bearing corrosion-preventive properties, for service in which regular-grade oils do not give satisfactory service. The heavy-duty grade is one having both the properties of the premium grade and detergent-dispersant properties, suitable for gasoline and high-speed diesel engines in heavy-duty service.

The regular grade may be divided into two subgrades, H. R. Wolf of General Motors said recently: a highly refined solvent-treated oil which oxidizes readily, and the conventionally refined oil which forms sludge and insoluble products under the same high-temperature conditions. The first shows the forming of corrosive and varnish-forming materials.

These definitions were developed by the marketing division of the A.P.I. and are definitions without any intention of their becoming specifications and without setting up minimum standards for these products. While use of the heavy-duty grade is not contemplated by either industry as a practical necessity, no intention is expressed or held, it is believed, to prevent the use of any grade in a service less severe than that for which it is defined specifically. In fact refiners in some instances are offering these super-oils in their filling stations as products suitable for passenger-car engines, an obvious fact of course. One large motor-car manufacturer issued the first printing of passenger-car instruction books, to accompany new cars to their private owners, in which books the first two grades were mentioned as satisfactory for operating these engines. Immediately refiners protested this matter stating that they wished to offer their heavy-duty grade also to retail and other passenger-car operators, in filling stations and elsewhere. Consequently this car maker arranged to have the entire list of three grades mentioned in the next instruction book printing as satisfactory, although the service is claimed not to be severe enough in general to demand use of the highest grade. Heavy-duty oils are being offered widely now by several refiners, and others expect to be forced by competition to meet the challenge in the near future. This trend is definite though how large a portion of total sales will be of this heavy duty grade in the next year or two cannot be foretold.

Refiners Studying Situation Carefully

Those refiners not now meeting this demand are considering carefully and watching the trend. A large solvent-refining capacity is available in the country. Some medium-to-small refiners are buying heavy-duty oils from those better equipped to make them, rather than install more processes. Those who remain independent in making lubricating oils must either use solvent units they have, install better units and buy additives, or both. Each step calls for more money spent in investment or buying outside-the-refinery materials. Some believe this course will be necessary in the near future, to meet competition of those already equipped and in the "improved" lubricant field, setting the pace for this trend. Other refiners believe that top-notch refining techniques combined with good lubricant crudes and good selling ability will for a considerable time at least make it unnecessary to market these ultra products.

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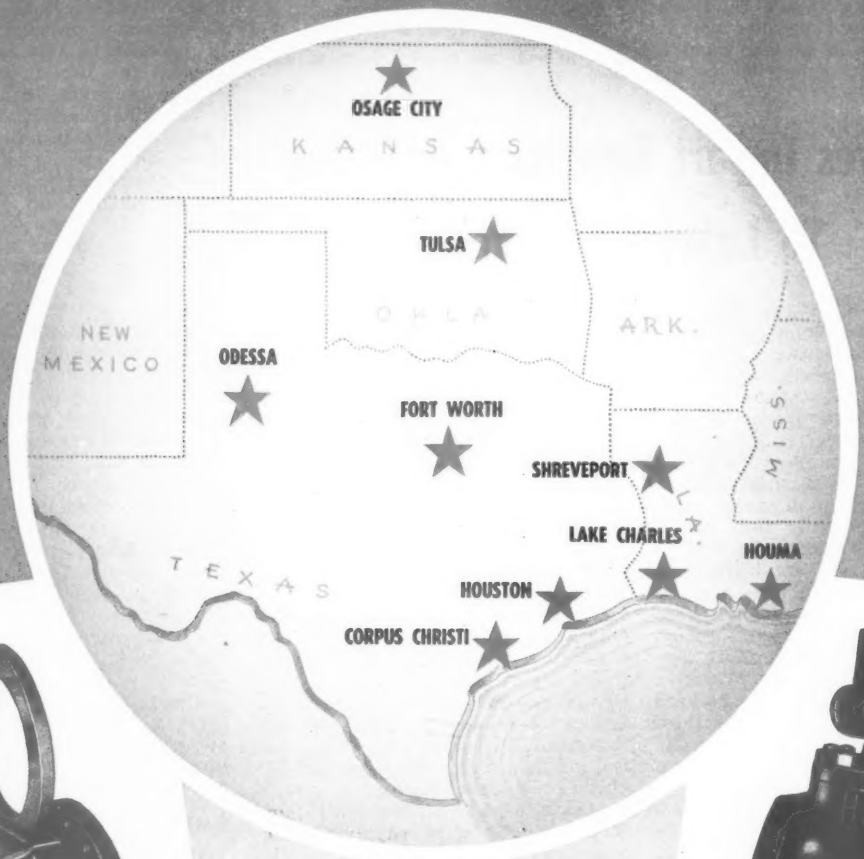

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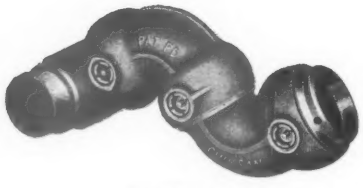

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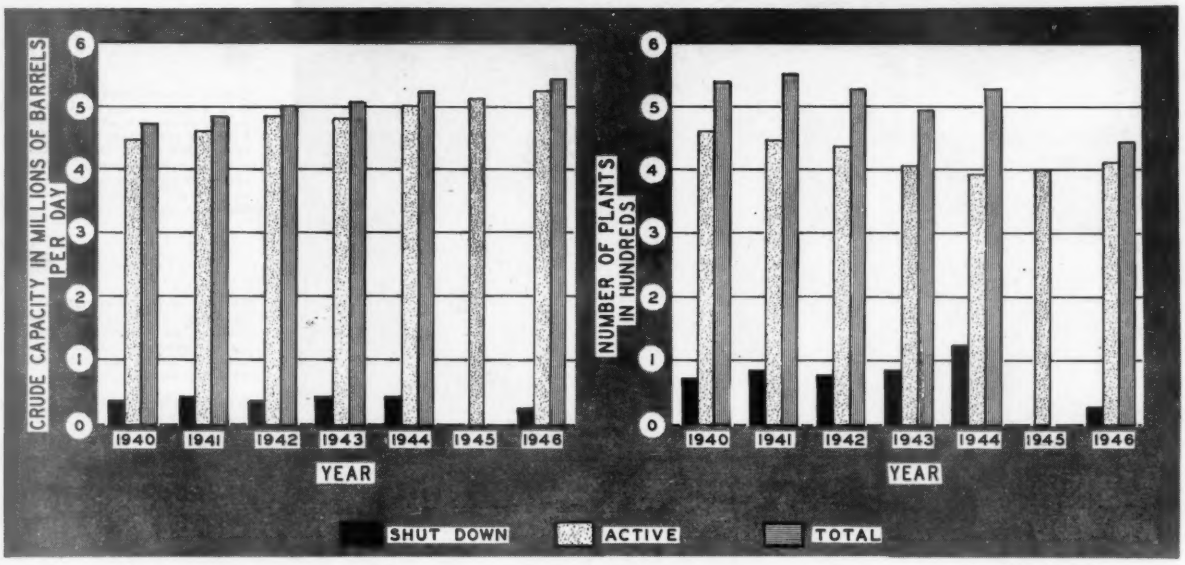


Crude capacity of refineries, active, shutdown, and total, 1940-46. The number of refineries, active, shutdown and total, shows a definite general trend downward, while the crude capacity per plant is consistently upward over this period

Refining Industry Trends to Larger Unit Capacity

by Arch L. Foster

THE size of the average refinery continues to increase slowly, according to the results of refinery surveys of the last 7 years. Although this figure showed a slight drop from 1945 to 1946 the trend of the curve is indubitably upward. This slight drop is caused, apparently by the reopening of refineries closed during the war owing to lack of crude supply or of a market for motor fuel, especially during the all-out-for-aviation-and-military-fuels period of 1945. Total crude capacity is up slightly for 1946 over 1945, an increase of about 96,000 bbl. per day.

Undoubtedly the largest question mark in the minds of refiners, so far as capacity is concerned, centers on disposition of the government-owned wartime catalytic cracking, alkylation and isomerization and other plants, most of which are shut down. Capacities of these government units—in barrels of charge stock per day, are:

Catalytic cracking	141,600
Alkylation	44,480
Isomerization	18,400
Total cost	$238,285,000

These plants are in indefinite status at present, as a group. Some are operating on a month-to-month rental basis, while the operators consider the matter of purchase, or negotiate with federal agencies concerning price and purchase conditions. A number are shutdown (see table) and public announcement has placed at least six installations on the open market. These installations include one to three units, each. The capacity represented by these plants, while far from a major portion of the potential capacity of the American industry, is large enough to cause market and supply troubles in either the aviation-fuel or motor-gasoline fields, if devoted to production of either product.

TRENDS IN NUMBER OF REFINERIES, TOTAL REFINING CAPACITY, AND AVERAGE PER PLANT, 1940-46

Year—	No. of refineries— Operating	Shutdown	Crude capacity— Total	Operating	Average refinery capacity
1940	462	70	4,665,318	4,438,658	9,600
1941	459	89	4,816,715	4,524,775	9,850
1942	445	74	5,039,815	4,793,635	10,800
1943	412	84	5,043,010	4,780,025	11,600
1944	394	129	5,232,550	4,977,400	12,650
1945	401	(*)	(*)	5,192,700	13,000
1946	411	25	5,431,995	5,288,600	12,860

*1945 shutdown capacity uncertain.

Curve Shows Dip

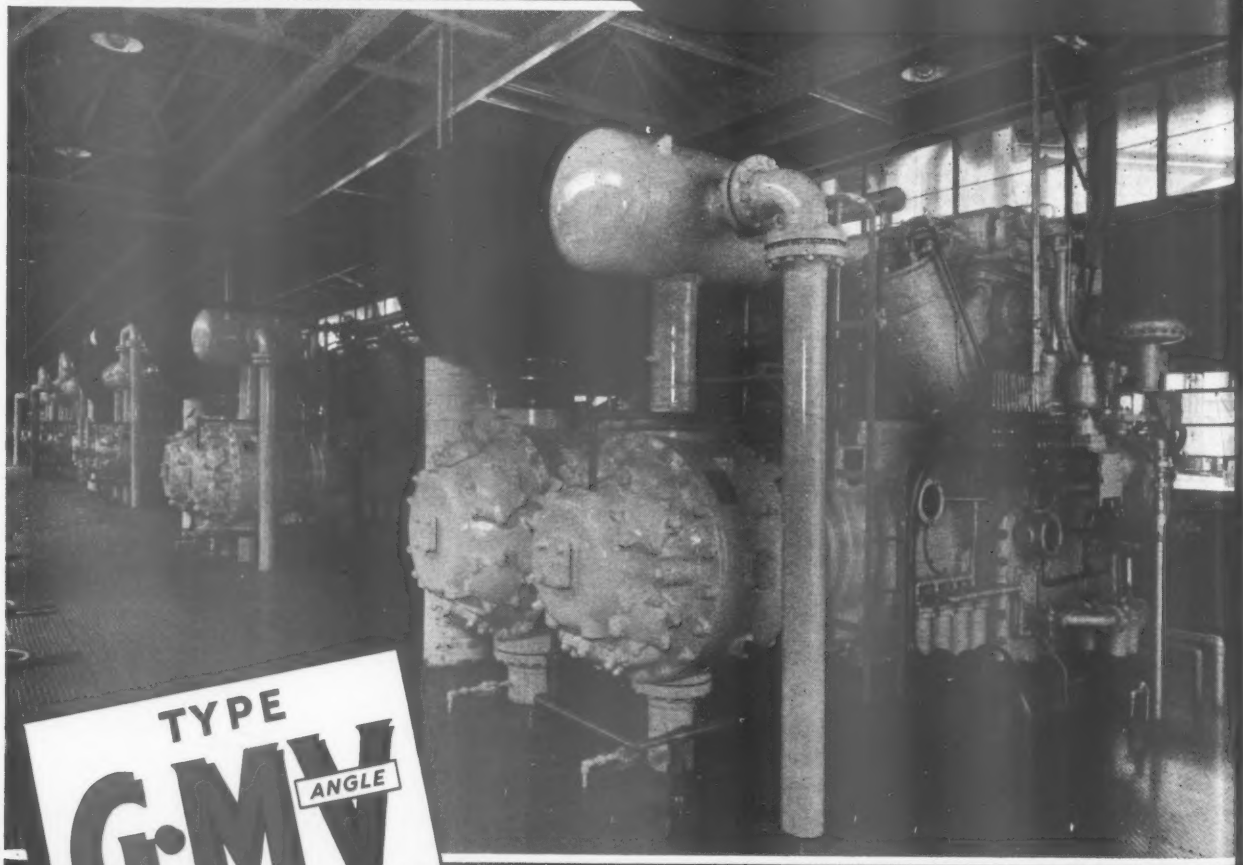
The curve on operating refineries shows a dip from 1943 to 1945, dropping from 412 plants to 394 in 1944 and back to 401 in 1945. This was an unnatural condition developed by the disturbance of economic balances during the war. Many smaller plants not manufacturing war products were unable to continue operations either because of nonallocation of crude supplies or scarcity of suitable personnel. Total operating capacity continued its upward trend. Closing of war plants, which presumably were reported as operating capacity in 1945, on the one hand, and the reopening of plants closed by the war raised the number of operating plants to 411 in 1946 without increasing the capacity correspondingly; therefore the average capacity per plant shows the slight reduction.

In individual states several sharp changes in conditions appear during the 1945 period. California shows an increase in operating refineries from 49 in 1945 to 55 in 1946, with a daily crude capacity increase of 77,000 bbl., caused no doubt by crude being made available to plants shutdown during earlier parts of the war period, and

GMV compressors in the Dow Styrene Plant total 4,400 horsepower, are shown here from the crankdoor side. The two GMV's in foreground are six-cylinder units, each rated 600 hp. Third compressor is an eight-cylinder, 800-hp ammonia unit.

Exterior view of compressor building at Dow Styrene Plant, Los Angeles, California, showing exhaust silencers, intake air cleaners and air storage tanks.

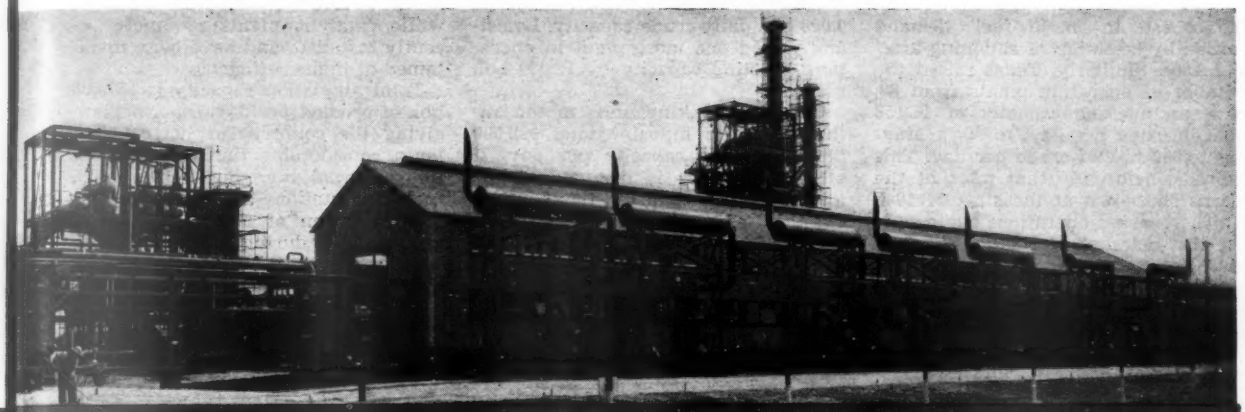
GMV "angles"



TYPE GMV ANGLE

Compressors

New York Washington Bradford, Pa. Parkersburg, W. Va. San Francisco, Cal. Seattle, Wash. Ho



for the Products of Tomorrow

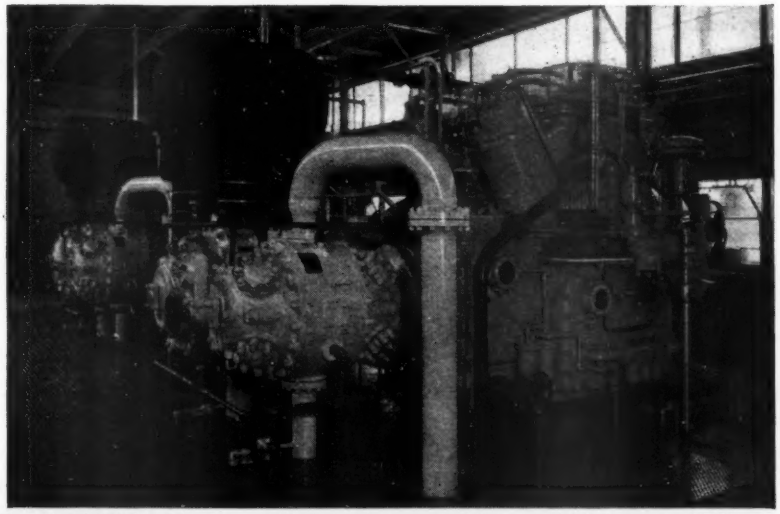
At The Dow Chemical Company's Styrene Plant, Los Angeles, California, seven modern GMV compressors help produce monomeric styrene as well as several other products, all having important peacetime applications.

As always, selection of compact, rugged GMV's made possible an economical and highly practical compressor setup. For example, fast, positive response to sensitive control instruments has been highly developed in the GMV, making it particularly desirable for modern processing requirements. Responsiveness is only one of the many phases of operation in which the GMV excels. Likewise there are exclusive features of design and construction that have helped earn for this modern 400, 600, 800 and 1000 hp compressor a reputation for truly exceptional service and performance.

The GMV Bulletin, 48 pages of data and interesting information, will be mailed in response to your request.

The seven GMV compressors installed in the Styrene Plant of The Dow Chemical Company are here shown from the compressor cylinder side. The fourth and fifth GMV's are eight-cylinder, 800-hp feed gas units. Compressors six and seven in this interesting line-up are GMV four-cylinder ethylene units.

Close-up of the two GMV-4 400-hp ethylene units showing compressor cylinders, piping and control equipment.



by **Cooper-Bessemer**

MOUNT VERNON, OHIO AND GROVE CITY, PENNA.

Houston, Dallas, Greggton, Pampa and Odessa, Texas Tulsa Shreveport St. Louis Los Angeles

the boost in motor-fuel demand caused by cessation of rationing after V-J Day. Similarly, Texas raised the number of operating plants from 88, with an average capacity of 17,150 bbl. of crude per day, to 96, averaging 15,600 bbl. of crude per day. This shows conclusively that most of the plants shutdown at the start of 1945 which resumed operations again during the year are of smaller capacity than the average.

Michigan refineries, however, declined two in the operating column, 20 in 1945, 18 in 1946, and lost nearly 9,000 bbl. daily crude capacity. Louisiana placed one more plant in operation, boosting capacity by 12,000 bbl. per day.

Catalytic-cracking units in the entire American industry total 928,000 bbl. of charge capacity per day. If all this capacity is included in the total cracking capacity figures then one-third of cracking capacity is catalytic. The ratio of catalytically cracked gasoline production potential is doubtless greater than these figures indicate, since much of the thermal capacity is old and inefficient, while catalytic plants are more recently installed, and have been maintained at higher efficiency.

Total alkylation capacity is 157,500 bbl. of product per day, reports show, giving the country surplus capacity for a considerable time to come for this essential ingredient of aviation fuel. Expectations are that a considerable portion of this capacity will remain idle during peacetime. The same may be said with greater emphasis for the isomerization capacity, shown to be 37,650 bbl. per day of product.

NORTH AMERICAN OPERATING REFINERIES

Their Capacities and Locations

SUMMARY OF ACTIVE PLANTS IN THE UNITED STATES—1946

	No. plants	Barrels daily: Crude-oil capacity	Barrels daily: Cracking capacity
Arkansas	7	48,400	16,750
California	55	964,100	537,450
Colorado	7	14,500	7,800
Delaware	1	3,500	.....
Georgia	1	4,000	.....
Idaho	1	2,100	530
Illinois	20	301,100	192,090
Indiana	8	254,300	128,650
Kansas	19	190,500	141,350
Kentucky	7	51,500	21,600
Louisiana	16	283,230	130,650
Maryland	4	62,900	17,500
Massachusetts	2	54,000	35,600
Michigan	18	90,950	34,950
Minnesota	2	4,500	.....
Mississippi	1	3,500	1,500
Missouri	1	26,500	18,500
Montana	10	42,650	17,600
Nebraska	6	7,650	800
New Jersey	6	278,000	93,250
New Mexico	9	16,950	5,740
New York	7	80,700	38,500
Ohio	10	209,200	209,400
Oklahoma	27	216,260	99,050
Pennsylvania	24	426,300	258,160
Rhode Island	3	10,400	1,800
South Carolina	1	6,000	.....
South Dakota	1	100	.....
Tennessee	2	6,000	1,500
Texas	96	1,496,215	1,025,300
Utah	4	23,100	15,800
Virginia	1	2,000	.....
Washington	1	6,000	2,800
West Virginia	4	14,000	17,700
Wisconsin	1	5,000	.....
Wyoming	28	82,300	36,600
Total	411	5,288,405	3,108,920

ABBREVIATIONS

Comp.—Complete plant, making gasoline, kerosene, distillate and residual fuel oils, lubricating oil, wax, and asphalt. S—Gasoline, kerosene, distillate and residual fuel oils. L—Lubricating oils. A—Asphalt. C—Same products as skimming, except plants are equipped with cracking. W—Wax. P—Petrochemical.

ARKANSAS

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
Berry Asphalt Co., Stephens	2,000	.....	S-A
Berry Asphalt Co., Waterloo	1,400	.....	S-L-A
Cross, Henry H., & Co., Smackover	6,000	.....	S-L-A
Lion Oil Ref. Co., El Dorado	17,000	†4,000	S-C-L-A
Macmillan Pet. Co., Norphlet	4,000	.....	S-L-A
Root Pet. Co., El Dorado*	15,500	†12,750	S-C
Stephens Ref. Co., Stephens	2,500	.....	S
Total	48,400	16,750	

CALIFORNIA

Bell Oil & Ref. Co., Santa Maria	7,500	4,000	S-C-A
Calstate Ref. Co., Long Beach	2,500	2,500	C
Caminol Co., Ltd., Hanford	3,100	600	S-C
Caminol Co., Ltd., Santa Fe Springs	3,500	1,100	S-C
Century Oil Co., Long Beach	5,000	.....	S
Eagle Oil & Ref. Co., Santa Fe Springs	5,000	1,500	S-C
Economy Asphalt Co., Oxnard	600	.....	A
El Camino Pet. Co., Los Angeles	1,000	.....	P
Elm Oil Co., Long Beach	3,000	.....	S
Envoy Pet. Co., Long Beach	4,000	.....	S-A
Exeter Ref. Co., Long Beach	10,000	.....	S-A
Field, O. C., Gasoline Corp., Casmalia	4,000	.....	S-A
Five C Ref. Co., Santa Maria	3,000	.....	S-A
Fletcher Oil Co., Wilmington	3,500	†1,200	S-C
General Pet. Corp., Lebec	23,000	.....	S
General Pet. Corp., Torrance*	90,000	59,000	S-C
Gilmore Oil Co., Vernon	2,000	.....	A
Golden Bear Oil Co., Bakersfield	2,500	.....	S-L-A
Hancock Oil Co. of California, Signal Hill, Long Beach	12,500	6,500	S-C
Harbor Refg. & Transportation Co., Wilmington	2,500	.....	S
Kreiger Oil Co. of California, Clearwater	3,200	.....	S-A
Kreiger Oil Co. of California, El Tejon (Bakersfield)	5,000	3,000	S-C
Lunday & Thagard, Downey	750	.....	A
Macmillan Pet. Corp., Long Beach	7,600	.....	S
McCallen Ref. Co., Huntington Beach	5,500	.....	S-A
Mohawk Pet. Corp., Bakersfield*	10,000	†4,800	S-C
Newhall Ref. Corp., Newhall	3,000	.....	S-A
Norwalk Co., Maricopa	7,500	.....	S
Pacific Coast Asphalt Co., Oxnard	400	.....	A
Pacific States Oil Co., Wilmington	25,000	.....	S
Palomar Ref. Co., Bakersfield	1,300	.....	S-L-A
Paraffine Cos., Inc., Emeryville	1,450	.....	A
Pathfinder Pet. Co., Los Angeles	.....	(†)	
Petrol Corp., Los Angeles	5,000	.....	A

CALIFORNIA (Continued)

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
Richfield Oil Co., (Wilmington) Watson*	80,000	†63,000	Comp.
Rothschild Oil Co., Santa Fe Springs	5,500	1,400	S-C
Seaside Oil Co., Ventura	4,500	.....	S
Shell Oil Co., Inc., Coalinga	6,700	.....	S
Shell Oil Co., Inc., Martinez*	45,000	26,000	Comp.
Shell Oil Co., Inc., (Wilmington) Watson*	52,000	52,000	S-C
Socal Oil & Ref. Co., Huntington Beach	2,000	500	S-C
Standard Oil Co. of Calif., El Segundo*	100,000	†1,450	Comp.
Standard Oil Co. of Calif., Richmond*	100,000	65,800	Comp.
Standard Oil Co. of Calif., Seguro	25,000	.....	S-A
Sunland Refg. Co., Fruitvale	2,000	.....	S
Texas Co., The, Fillmore	4,000	†3,600	S-C
Texas Co., The., Los Angeles*	40,000	28,000	S-C
Tide Water Assoc. Oil Co., (Associated) Avon*	60,900	†51,400	Comp.
Tide Water Assoc. Oil Co., Santa Maria	1,200	900	S-C
Tide Water Assoc. Oil Co., (Wilmington) Watson	14,000	8,200	S-C
Triangle Oil & Refining Co., Venice	2,500	.....	S
Union Oil Co. of Calif., (Maltha) Bakersfield	8,500	.....	S-A
Union Oil Co. of Calif., Oleum*	35,000	24,000	Comp.
Union Oil Co. of Calif., Wilmington*	104,000	51,000	S-C-A
Western Asphalt & Refg. Co., Santa Maria	500	.....	S-A
Wilshire Oil Co., Inc., Norwalk*	20,000	†6,000	S-C
Total	964,100	537,450	

COLORADO

Bay Pet. Corp., Denver	5,000	†1,900	S-C
Continental Oil Co., Denver	2,700	1,500	S-C
Gordon Ref. Co., Fort Morgan	200	.....	S
Oriental Ref. Co., Alamosa	1,100	900	S-C
Oriental Ref. Co., Denver	1,500	1,000	S-C
Perry Pet. Co., Denver	1,000	500	S-C
Texas Co., The, Craig	3,000	2,000	S-C
Total	14,500	7,800	

DELAWARE

Texas Co., The, Claymont	3,500	.....	S-A

GEORGIA

Mexican Pet. Corp. of Ga., Savannah	4,000	.....	A

IDAHO

Idaho Ref. Co., Pocatello	2,100	530	S-C

ILLINOIS

Advance Ref. Co., Centralia	2,800	.....	S
Allied Oil Corp., St. Elmo	5,000	2,200	S-C
Arrow Pet. Co., Centralia	3,500	.....	S
Calumet Ref. Co., Burnham	1,200	.....	L
Cascade Ref. Co., Salem	2,600	590	S-C
Cross, Henry H., Co., Colmar	1,000	.....	S
Cross, Henry H., Co., Dupo	1,000	.....	S
Globe Oil & Ref. Co., Lemont	27,000	5,500	S-C
Ohio Oil Co., The, Robinson	15,000	†9,000	S-C-A
Pana Ref. Co., Pana	4,000	1,600	S-C
Red River Ref. Co., Burnham	1,100	.....	S
S & D Refinery, Dupo	2,300	.....	S
Shell Oil Co., Inc., Wood River*	80,000	†45,000	Comp.
Socony-Vacuum Oil Co., Inc., E. St. Louis*	20,000	25,000	S-C
Standard Oil Co. (Ind.), Wood River*	31,000	27,200	Comp.
Texas Co., The, Lawrenceville	30,000	†19,000	S-C-L-A
Texas Co., The, Lockport*	50,000	†52,000	S-C-L-A
Wireback, B. F., Plymouth	600	.....	S
Wood River Oil & Ref. Co., Hartford	16,000	5,000	S-C
Worth Ref. Co., Blue Island	7,000	.....	S
Total	301,100	192,090	

INDIANA

Cities Service Oil Co. (Del.), E. Chicago*	30,000	†18,000	S-C
Indiana Farm Bur. Coop., Mount Vernon	4,000	.....	S
Johnson Oil Supply Co., Gary	3,500	.....	S
Rock Island Ref. Corp., Rock Island	6,000	†4,000	S-C
Sinclair Ref. Co., E. Chicago*	55,000	†30,000	Comp.
Socony-Vacuum Oil Co., Inc., E. Chicago*	23,000	†16,650	S-C
Standard Oil Co. (Ind.), Whiting*	132,000	†60,000	Comp.
Troy Ref. Corp., Trop	800	.....	S
Total	254,300	128,650	

KANSAS

Bareco Oil Co., Wichita	6,000	†3,250	S-C
Bay Pet. Corp., McPherson	6,000	†3,000	S-C
Chanute Ref. Co., Chanute	1,000	.....	S
Coop. Refinery Association, Coffeyville*	11,000	†5,700	S-C-L-W
Coop. Refinery Association, Phillipsburg	4,200	†1,800	S-C
Derby Oil Co., Wichita	8,000	†4,000	S-C-A

KANSAS (Continued)

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
El Dorado Ref. Co., El Dorado	8,500	3,200	S-C
H & T Reclaiming & Refg. Co., Chase	2,000	.....	S
Kanotex Ref. Co., Arkansas City	8,500	4,500	S-C-A
M. F. A. Ref. Co., Chanute	1,600	1,000	S-C
Natl. Coop. Refinery Association, McPherson	18,000	28,000	S-C
Phillips Pet. Co., Kansas City*	27,000	34,000	S-C
Shallow Water Ref. Co., Shallow Water	2,500	300	S-C-A
Sinclair Ref. Co., Coffeyville	11,000	†7,000	Comp.
Sinclair Ref. Co., Kansas City	12,000	†7,000	S-C
Skelly Oil Co., El Dorado	25,000	†15,000	S-C-A
Socony-Vacuum Oil Co., Inc., Augusta*	23,000	16,500	S-C-A
Standard Oil Co. (Ind.), Neodesha	7,700	4,600	Comp.
Vickers Pet. Co., Potwin	5,500	†2,500	S-C
Total	190,500	141,350	

KENTUCKY

Aetna Oil Co., Louisville	8,000	4,500	S-C
Ashland Oil & Ref. Co., Catlettsburg*	20,000	†6,000	Comp.
Louisville Ref. Co., Louisville	6,000	†2,500	S-C
South Kentucky Pipe Line Co., Somerset	400	.....	S
Sohio Petroleum Corp., Covington	14,100	†8,600	S-C-A
Stoll Oil & Refining Co., Louisville	1,800	.....	S
Slagter Oil & Grease Co., Spottsville	1,200	.....	S
Total	51,500	21,600	

LOUISIANA

Atlas Oil & Ref. Co., Shreveport	12,000	†6,000	S-C
Bayou State Oil Co., Hosston	800	.....	S-L
Bunkie Oil & Ref. Co., Eola (Bunkie)	800	.....	S
Chalmette Pet. Corp., Chalmette	8,000	†2,500	S-C
Cities Service Ref. Corp., Lake Charles*	70,000	59,750	S-C
Clark's Super Gas Co., Marrero	3,500	2,000	S-C
Coast Oil Co., Cotton Valley	2,500	.....	S
Continental Oil Co., Lake Charles*	8,000	4,000	S-C
Evangeline Ref. Co., Jennings	1,000	.....	S-L
Ohio Farm Bureau Coop., Meraux	3,200	.....	S
Pan American Pet. Corp., Destrehan	8,000	.....	S-A
Premier Oil Ref. Co., Cotton Valley	6,500	.....	S
Princeton Ref. Co., Princeton	630	.....	S-L-A
Shell Oil Co., Inc., Norco*	25,000	†18,900	S-C-A
Standard Oil Co. of La., Baton Rouge	130,000	†35,300	Comp.
Stanolind Oil & Gas Co., (Superior) Vivian	3,300	2,200	S-C
Total	283,230	130,650	

MARYLAND

American Bitumuls, Baltimore	2,400	.....	A
Continental Oil Co., Baltimore	7,500	3,500	S-C-A
Pan American Ref. Corp., Baltimore	8,000	.....	S-A
Standard Oil Co. of N. J., Baltimore	45,000	14,000	Comp.
Total	62,900	17,500	

MASSACHUSETTS

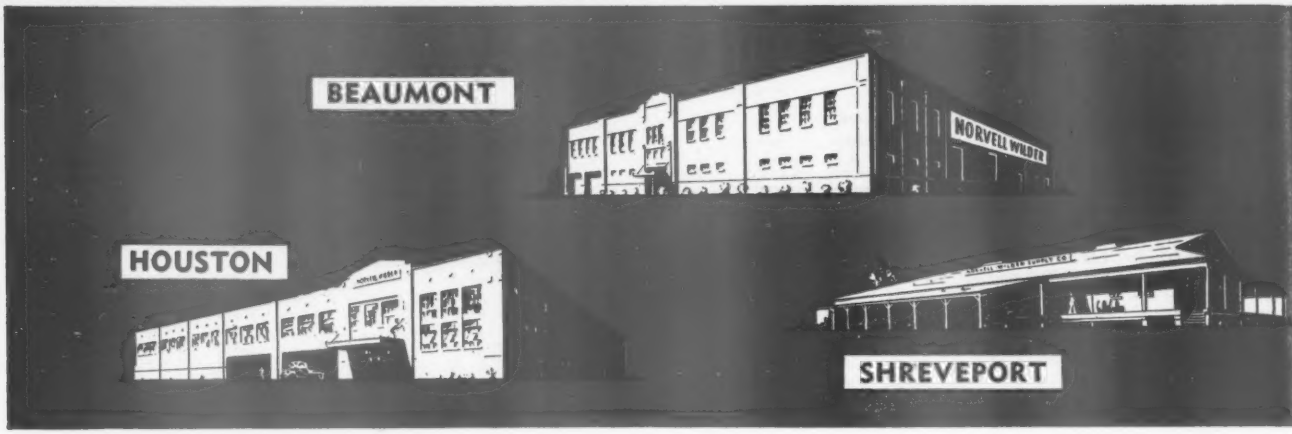
Cities Service Oil Co. (Pa.), E. Braintree	20,000	3,600	S-C
Colonial Beacon Oil Co., Everett	34,000	†32,000	S-C-A
Total	54,000	35,600	

MICHIGAN

Aurora Gasoline Co., Detroit	6,000	†3,000	S-C
Aurora Gasoline Co., Elsie	3,500	.....	S
Bay Ref. Co., Bay City	4,500	.....	S
Crystal Ref. Co., Carson City	6,500	.....	S
Lakeside Ref. Co., Kalamazoo	1,700	.....	S
Leonard Refineries, Inc., Alma*	8,000	†3,200	S-C-A
Louis Rose Refining Co., Saginaw	1,000	.....	S
Marvel Ref. Co., Grand Rapids	2,000	.....	S
Mid-West Refineries, Alma	3,500	†1,750	S-C
Mid-West Refineries, Grandville	4,500	†2,000	S-C
Naph-Sol Ref. Co., Muskegon	5,000	†2,500	S-C
Old Dutch Ref. Co., Muskegon	4,500	†2,000	S-C
Osceola Ref. Co., Reed City	2,000	.....	S
Petroleum Specialties, Inc., Flat Rock	3,000	1,000	S-C
Producers Ref. Co., Inc., West Branch	3,500	.....	S
Pure Oil Co., Midland	5,500	.....	S
Roosevelt Oil Co., Mount Pleasant	5,000	.....	S
Socony-Vacuum Oil Co., Inc., Trenton*	21,250	†19,500	S-C
Total	90,950	34,950	

MINNESOTA

Northwestern Ref. Co., St. Paul Park	3,500	.....	S-A
Comet Refinery Co., New Britton	1,000	.....	S
Total	4,500	.....	



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Hewitt Rubber Corp.—Packing, Hose
Hughes Tool Company—Valves
Kennedy Valve Mfg. Co.—Valves, Fittings
Ladish Drop Forge Company—Flanges, Forgings
A. Leschen & Sons Rope Company—Wire Rope
The Lunkenheimer Company—Valves, Steam Specialties
Merco Nordstrom Valve Company—Plug Valves
Pittsburgh Steel Company—Stainless Tubes, Still Tubes, Carbon Moly Pipe
Quigley Company—Refractories, Insulation Material
Reed Roller Bit Company—Valves
Republic Steel Company—Line Pipe, Condenser Tubes
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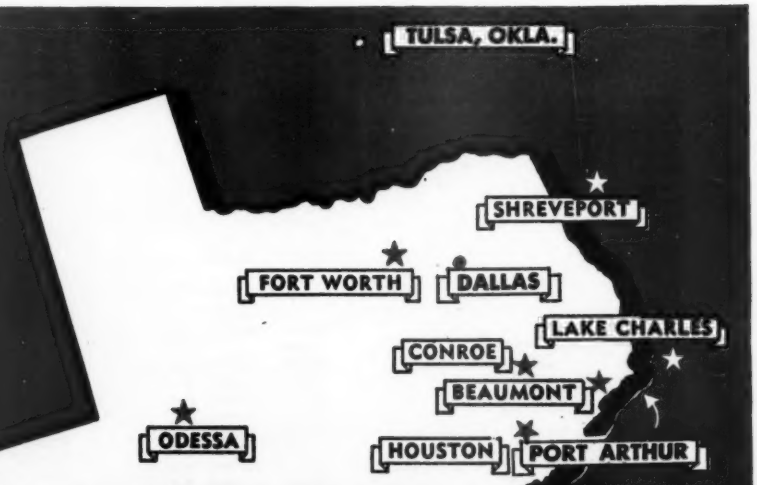


35 YEARS

OF SPECIALIZED SERVICE TO THE OIL INDUSTRY

MISSISSIPPI

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
Paluxy Asphalt Co., Yazoo City	3,500	1,500	S-C-A

MISSOURI

Standard Oil Co. (Ind.), Sugar Creek*	26,500	†18,500	Comp.

MONTANA

Big West Oil Co., Kevin	1,500	†1,000	S-C
Carter Oil Co., Billings	10,600	900	S-C-A
Carter Oil Co., Cut Bank	4,000	†1,400	S-C
Farmers Union Cent. Ex'ch., Laurel	11,500	†4,500	S-C-A
Hart Refineries, Missoula	550	.....	S
Hole Brothers Refinery, Cut Bank	350	.....	S
Home Oil & Ref. Co., Great Falls	2,250	†1,100	S-C-A
Texas Co., The, Sunburst	7,500	6,000	S-C
Treasure State Ref. Co., Shelby	500	.....	S
Union Oil Co. of Calif., Cut Bank	4,500	†2,700	S-C
Total	156,500	17,600	

NEBRASKA

Coop. Refinery Association, Scottsbluff	1,800	800	S-C
Mid-States Ref. Co., Falls City	3,000	.....	S
Nebraska Prod. & Ref. Co., Salem	800	.....	S
Petroleum Utilities, Inc., Chadron	750	.....	S
Porter Oil Co., Sidney	300	.....	S
Searle Pet. Co., Omaha	1,000	.....	S
Total	7,650	800	

NEW JERSEY

Barber Asphalt Co., Barber	15,000	4,000	S-C-A
Cities Service Oil Co., Linden	12,000	.....	S-A
Cities Service Oil Co., Petty's Island	20,000	.....	S-A
Socony-Vacuum Oil Co., Inc., Paulsboro*	25,000	25,750	Comp.
Standard Oil Co. of N. J., Linden	136,000	31,000	Comp.
Tide Water Associated Oil Co., Bayonne*	70,000	32,500	Comp.
Total	278,000	93,250	

NEW MEXICO

Aerex Co., Bloomfield	100	.....	S
Continental Oil Co., Farmington	750	.....	S
Continental Oil Co., Artesia	1,500	640	S-C
Malco Refineries, Artesia	3,000	1,200	S-C
McNutt Oil & Ref. Co., Brickland	2,000	600	S-C
New Mexico Asphalt & Ref. Co., Artesia	5,000	2,500	S-C-A
Petroleum Products Ref. & Prod., Prewitt	1,500	.....	S
Valley Ref. Co., Roswell	2,500	800	S-C
Warren Pet. Corp., Monument	600	.....	S
Total	16,950	5,740	

NEW YORK

Allegany Refiners, Inc., Bolivar	2,700	.....	L-W
Frontier Fuel Oil Corp., Tonawanda	7,500	2,500	S-C
Gulf Oil Corp., Gulf Port, Staten Island	14,000	.....	S
Sinclair Ref. Co., Wellsville	11,000	6,000	Comp.
Socony-Vacuum Oil Co., Inc., Brooklyn and Long Island City*	21,000	†16,000	Comp.
Socony-Vacuum Oil Co., Inc., Buffalo*	18,500	14,000	Comp.
Socony-Vacuum Oil Co., Inc., Olean	6,000	.....	Comp.
Total	80,700	38,500	

OHIO

Canton Ref. Div. of Central Pipe Line Co., Canton	10,000	†2,000	S-C
Erie Ref. Co., Warren	2,200	.....	S
Gulf Ref. Co., Cleves	26,600	14,000	S-C-A
Gulf Ref. Co., Toledo	23,000	10,000	S-C
Pure Oil Co., Toledo*	29,400	†61,100	S-C
Pure Oil Co., Newark	15,500	†36,200	S-C
Standard Oil Co. (Ohio), Toledo*	20,000	†7,200	S-C-L
Standard Oil Co. (Ohio), Lima	10,500	†6,900	S-C
Standard Oil Co. (Ohio), Cleveland*	37,000	†41,000	Comp.
Sun Oil Co., Toledo*	35,000	†31,000	S-C
Total	209,200	209,400	

OKLAHOMA

Allied Materials Corp., Stroud	1,200	.....	S-A
Anderson-Prichard Ref. Corp., Cyril*	10,000	5,000	S-C-A
Bareco Oil Co., Barnsdall	3,500	2,250	S-C-L-W
Bell Oil & Gas Co., Granfield	5,000	2,600	S-C
Ben Franklin Ref. Co., Ardmore	5,000	†2,800	S-C
Caddo County Ref. Co., Cement	2,500	.....	S
Champlin Ref. Co., Enid	16,000	6,000	Comp.
Cities Service Oil Co., Ponca City	11,000	4,500	Comp.
Continental Oil Co., Ponca City*	26,000	†23,200	Comp.
Cosco Oil Co., Wynnewood	3,000	600	S-C-A
Deep Rock Oil Corp., Cushing	12,000	†2,500	Comp.
Denver Prod. & Ref. Co., Edmond	2,000	.....	S

OKLAHOMA (Continued)

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
Fen-Tar Refining Co., Wynnewood	3,500	1,350	S-C-A
Johnson Oil Ref. Co., Cleveland	5,500	†2,750	S-C
Mercury Oil Ref. Co., Oklahoma City	2,500	1,200	S-C
Mid-Continent Pet. Corp., Tulsa	30,000	8,500	Comp.
Midland Coop. Wholesale, Cushing	4,000	†1,400	S-C
Monarch Refineries, Inc., Oklahoma City	1,000	.....	S-A
Peppers Gasoline Co., Oklahoma City	1,500	300	S-C
Phillips Pet. Co., Okmulgee	7,000	6,000	Comp.
Rock Island Ref. Co., Beckett (Duncan)	8,000	4,000	S-C-A
Shale Oil Co., Lawton	60	.....	S
Sinclair Ref. Co., Sand Springs	7,000	3,000	Comp.
Sunray Oil Co., Allen	10,000	†1,800	S-C
Texas Co., The, West Tulsa	22,000	12,000	Comp.
Tide Water Associated Oil Co., Drumright	12,000	†5,000	S-C
Wilcox, H. F., Oil & Gas Co., Bristow	5,600	†2,300	S-C
Total	216,260	99,050	

PENNSYLVANIA

Atlantic Ref. Co., Philadelphia*	95,000	†68,300	Comp.
Berry, James B., Sons Co., Oil City	2,500	1,500	Comp.
Bradford Penn Ref. Corp., Clarendon	1,500	.....	S-L
Canfield Oil Co., Coraopolis	1,000	.....	S-L
Cities Service Oil Co. (Pa.), Titusville	3,000	.....	S-L-A
Continental Ref. Co., Oil City	1,000	400	Comp.
Daugherty Refinery (L. Sonneborn Sons), Petrolia	4,000	.....	S-L-W
Franklin Creek Ref. Corp., Franklin	2,000	.....	S-L
Freedom-Valvoline Oil Co., Freedom	3,300	†600	S-C-L-W
Freedom-Valvoline Oil Co., Butler	2,500	.....	S-L-W
Gulf Oil Corp., Pittsburgh	14,500	6,000	S-C
Gulf Oil Corp., Philadelphia*	62,000	25,000	S-C-L
Kendall Ref. Co., Bradford	5,000	†2,200	Comp.
Pennsylvania Ref. Co., Titusville	2,000	.....	S-L
Pennsylvania Ref. Co., Karns City	1,000	.....	S-L-W
Pennzoil Co., The, Rouseville	8,500	†7,600	S-C-L-W
Quaker State Oil & Ref., Emlenton	2,000	1,100	Comp.
Quaker State Oil & Ref., Farmers Valley	4,000	1,500	Comp.
Sherwood Ref. Co., Inc., Warren	1,000	.....	L
Sinclair Ref. Co., Marcus Hook	65,000	†40,000	S-C
Sun Oil Co., Marcus Hook*	135,000	101,000	Comp.
United Ref. Co., Warren	5,500	†2,000	Comp.
Waverly Oil Works, Pittsburgh	2,500	.....	S-L-W
Wolf's Head Ref. Co., Inc., Reno and Oil City	2,500	960	S-C-L-W
Total	426,300	258,160	

RHODE ISLAND

American Bitumuls, E. Providence	1,400	.....	S-A
Socony-Vacuum Oil Co., Inc., E. Providence	5,500	1,800	S-C-A
Texas Co., The, Providence	3,500	.....	S-A
Total	10,400	1,800	

SOUTH CAROLINA

Standard Oil Co. of N. J., Charleston	6,000	.....	S-A

SOUTH DAKOTA

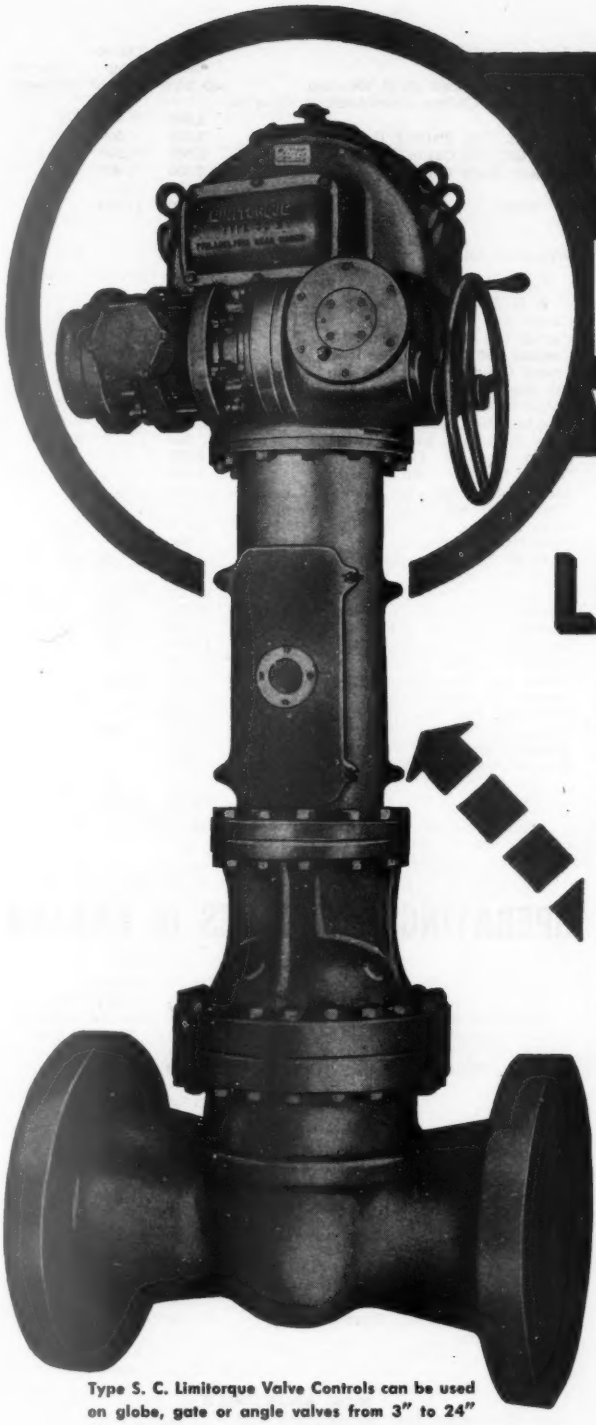
Sturgis Ref. Co., Sturgis	100	.....	S

TENNESSEE

Delta Ref. Co., Memphis	5,000	1,500	S-C-A
Southern Oil Service, Nashville	1,000	.....	S
Total	6,000	1,500	

TEXAS

American Mineral Spirits Co., Corpus Christi	10,000	.....	S
American Republics Corp., Houston	6,500	.....	S
Atlantic Ref. Co. (Atreco), Port Arthur*	24,300	†28,200	S-C
Baird Ref. Co., Baird	2,000	1,200	S-C
Bryson Pipe Line & Ref. Co., Bryson	1,500	250	S-C
Caprito Refinery, Post	500	.....	S
Clymore Co., Inc., Pettus	1,300	.....	S
Coastal Refineries, Inc., Port Isabel	7,000	2,500	S-C
Col-Tex Ref. Co., Colorado City	10,000	4,000	S-C-A
Consumers Cooperative Refy. Assn., Levelland	5,400	2,700	S-C
Continental Oil Co., Wichita Falls*	5,000	†2,600	S-C
Cosden Pet. Corp., Big Spring	15,000	†13,000	S-C
Cosden Pet. Corp., Graham	2,500	.....	S
Crown Central Pet. Corp., Houston*	18,000	4,000	Comp.
Danaho Ref. Co., Pettus	2,500	.....	S
Danciger Oil & Ref. Co., Pampa	7,000	†3,500	S-C
Eastern States Pet. Co., Houston*	30,000	19,000	S-C
Flint Chemical Co., San Antonio	500	.....	S
Gladewater Ref. Co., Gladewater	2,500	1,200	S-C
Gratex Ref. & Fuel Oil Co., Graham	300	.....	S



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TEXAS (Continued)

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
Great Southern Corp., Corpus Christi*	6,500	2,000	S-C
Gulf Oil Corp., Sweetwater	3,400	4,000	S-C
Gulf Oil Corp., Fort Worth	7,200	4,000	S-C
Gulf Oil Corp., Port Arthur*	167,200	†75,000	Comp.
Hamman Oil & Ref. Co., Bay City	3,000	.....	S-W
Heffington Refining Co., Austin	200	.....	S
Henderson, Frank C., Trust 2, Banquete	200	.....	S
Humble Oil & Ref. Co., Baytown*	180,000	†135,900	Comp.
Humble Oil & Ref. Co., San Antonio	7,000	.....	S
Huntex Oil & Ref. Co., Hardin	700	.....	S
Independent Ref. Co., Arp.	4,000	†2,000	S-C
Inland Refining Co., Palestine (Tucker)	2,000	.....	S
Jacksboro Refining Co., Jacksboro	100	.....	S
Lacy, R., Refinery, Kilgore	2,500	700	S-C
La Salle Pet. Corp., Burkburnett	2,500	.....	S
Magnolia Pet. Co., Fort Worth	12,000	†9,300	S-C
Magnolia Pet. Co., Beaumont*	110,000	†104,000	Comp.
Maritime Oil Co., Houston	5,000	.....	S
Master Pet. Co., Dallas	1,500	.....	S
McBride Ref. Co., La Blanca	2,500	.....	S-L-A
McMurrey Refining Co., Tyler	9,000	1,500	S-C
Mid-Co Gasoline Co., Cayuga	200	.....	S
Minerva Ref. Co., Minerva	1,250	.....	S
Moutray Oil Co., Hawley	1,000	500	S-C
Muenster Refining, Inc., Muenster	120	.....	S
Nueces Ref. Co., Clarkwood	2,500	.....	S
Onyx Ref. Corp., Hawley	3,000	800	S-C
Pan American Ref. Corp., Texas City*	100,000	†37,000	Comp.
Panhandle Ref. Co., Wichita Falls	4,000	†1,800	S-C
Panhandle Ref. Co., Lueders	1,500	700	S-C
Patton Oil Co., Rotan	900	.....	S
Payward Ref. Co., Shamrock	700	.....	S
Peerless Tank Cleaning Co., Kilgore	150	.....	S
Petroleum Wax Co., Kilgore	100	.....	S
Petrolite Corp., Ltd., Kilgore	100	.....	S
Phillips Pet. Co., Borger	44,000	†95,000	S-C
Phoenix Ref. Co., Houston	2,500	.....	S
Pioneer Oil & Ref. Co., Somerset	800	.....	S-A
Pontiac Ref. Co., Corpus Christi	20,000	.....	S
Premier Oil Ref. Co., Longview	4,500	†3,000	S-C
Premier Oil Ref. Co., Fort Worth	3,400	800	Comp.
Prichard Ref. Co., San Antonio	1,500	.....	S
Pure Oil Co., Nederland*	55,000	†98,000	S-C
Rado Ref. Co., McAllen	1,000	.....	S
Refugio Refining Co., Refugio	1,500	.....	S
Reischman, R. J., Refinery, Fort Stockton	200	.....	S
Republic Oil Ref. Co., Texas City*	25,000	22,000	S-C
Shamrock Oil & Gas Corp., Sunray	6,000	†4,000	S-C
Shell Oil Co., Inc., Houston (Deer Park)*	†74,000	†54,000	S-C
Shelly Ref. Co., Inc., Chalmers (Bay City)	2,200	250	S-C
Sinclair Ref. Co., Corpus Christi*	27,000	20,000	S-C
Sinclair Ref. Co., Houston*	73,000	62,000	S-C-L-A
Sinclair Ref. Co., Fort Worth	6,500	4,500	S-C
Skelly Oil Co., Longview	10,000	2,600	S-C
Southport Pet. Co., Texas City	18,500	2,000	S-C
Southwestern Oil & Ref. Co., Corpus Christi	16,000	.....	S
Standard Oil Co. of Texas, El Paso	14,000	5,000	S-C
Star Light Ref. Co., Hatchel	600	.....	S
Stone Oil Co., Texas City	7,500	.....	S
Talco Asphalt & Ref. Co., Mount Pleasant	12,000	2,000	S-C
Taylor Ref. Co., Corpus Christi	22,500	3,800	S-C
Texas Co., The, Houston	27,500	.....	S
Texas Co., The, Amarillo	7,500	4,000	S-C
Texas Co., The, El Paso	2,500	2,000	S-C
Texas Co., The, Port Arthur*	135,000	†156,500	Comp.
Texas Co., The, San Antonio	6,000	6,000	S-C
Texas Co., The, West Dallas	15,000	†14,000	S-C
Texas Co., The, Port Neches	40,000	.....	S-A
Texas Pacific Coal & Oil Co., Caddo	600	.....	S
Three Rivers Refinery, Three Rivers	1,500	.....	S-L-A
Tydal Ref. Co., Gainesville	1,500	.....	S
United Gas Pipe Line Co., Beeville	595	.....	S
Uvalde Rock Asphalt Co., Blewett	500	.....	S
Waggoner, W. T., Estate, Electra	7,000	†2,500	S-C
Western Ref. Co., Baldridge (Fort Stockton)	1,000	.....	S
Wickett Ref. Co., Wickett	2,000	.....	S
Total	1,496,215	1,025,300	

UTAH

Tri-State Oil & Ref. Co., Relico (Ogden)	500	.....	S
Uinta Oil Co., Vernal (Jensen)	400	.....	S
Utah Oil Ref. Co., Salt Lake City*	16,000	14,400	Comp.
Wasatch Oil Ref. Co., Woods Cross	2,200	†1,400	S-C-A
Total	23,100	15,800	

VIRGINIA

Texas Co., The, Norfolk	2,000	.....	S-A

WASHINGTON

Inland Empire Refineries, Spokane	6,000	†2,800	S-C-A

WEST VIRGINIA

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
Carbide & Carbon Chemicals, S. Charleston	2,500	500	S-C
Elk Ref. Co., Falling Rock	3,500	1,500	S-C
Pure Oil Co., Cabin Creek	5,500	†14,300	Comp.
Quaker State Oil Ref. Co., St. Marys	2,500	†1,400	S-C-L
Total	14,000	17,700	

WISCONSIN

Wisconsin Oil Ref. Co., Sheboygan	5,000	.....	S

WYOMING

C. & H. Refinery, Lusk	80	.....	S
Carter Oil Co., Lovell	3,000	.....	S-A
Carter Oil Co., Newcastle	1,600	900	S-C
Continental Oil Co., Glenrock	3,400	†1,800	S-C
Crook County Refinery, Sundance	175	.....	S
Elk Horn Gas Refinery, Osage	55	.....	S
Empire State Oil Co., Thermopolis	1,000	.....	S-A
Frontier Ref. Co., Cheyenne*	5,000	†3,250	S-C
Gray Refinery, Inc., Newcastle	600	.....	S
Husky Ref. Co., Cody	5,000	.....	S-A
Husky Ref. Co., Riverton	5,200	.....	S
Independent Ref. Co., Lusk	120	.....	S
Manewal-Bradley Oil Co., Osage	350	.....	S
Ohio Oil Co., The, Lovell	5,000	.....	S-A
Pilot Oil Co., Morton	300	.....	S
Resolute Oil Corp., Badger Basin	500	300	S-C
Silver Tip Refinery, Yoder	100	.....	S
Sinclair Ref. Co., Sinclair*	14,000	13,000	S-C-A
Socony-Vacuum Oil Co., Inc., Casper	5,000	1,000	S-C-A
Standard Oil Co. (Ind.), Greybull	5,500	1,900	Comp.
Standard Oil Co. (Ind.), Casper	13,000	6,350	Comp.
Texas Co., The, Calpet	400	.....	S
Texas Co., The, Casper	7,000	†7,200	S-C
Texas Co., The, Cody	3,000	.....	S-A
Tri-State, Inc., Thermopolis	500	.....	S-A
Wasatch Prod. Co., Woods Cross	2,200	900	S-C-A
Wheatco Ref. Co., Wheatland	120	.....	S
Z & W Service & Refinery, Torrington	100	.....	S
Total	82,300	36,600	

*See table of Catalytic and Associated Units for additional information on refinery.

†Polymerization included.

OPERATING REFINERIES IN CANADA

ALBERTA

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
British-American Oil Co., Ltd., Calgary	5,000	2,500	S-C-A
Gas & Oil Refineries, Ltd., Hartell	2,000	†1,000	S-C
Imperial Oil, Ltd., Calgary	8,300	2,000	S-C-A
Total	15,300	5,500	

BRITISH COLUMBIA

Imperial Oil, Ltd., Ioco	16,000	600	Comp.
Shell Oil Co. of B. C., Shelburn	4,200	.....	S
Standard Oil Co. of B. C., Ltd., Vancouver	5,000	.....	S-A
Total	25,200	600	

MANITOBA

Anglo-Canadian Oils, Ltd., Brandon	2,000	700	S-C
North Star Oil, Ltd., St. Boniface	2,000	750	S-C-A
Radio Oil Ref., Ltd., Winnipeg*	700	.....	S
Miscellaneous	450	.....	
Total	5,150	1,450	

NEW BRUNSWICK

New Brunswick Gas & Oilfields, Ltd., Weldon	300	.....	S

NORTHWEST TERRITORIES

Northwest Co., Ltd., Fort Norman	850	.....	S

NOVA SCOTIA

Imperial Oil, Ltd., Dartmouth	34,000	3,900	S-C-A

ONTARIO

British-American Oil Co., Ltd., Clarkson	8,300	4,400	S-C
British-American Oil Co., Ltd., Toronto	6,000	3,000	Comp.
Burlington Refineries, Ltd., Hamilton*	600	.....	S
Canadian Oil Companies, Ltd., Petrolia	4,000	†2,000	Comp.
Goodrich Ref. Co., Ltd., Port Credit	5,000	2,000	S-C
Imperial Oil, Ltd., Sarnia	41,500	10,700	Comp.
McColl-Frontenac Oil Co., Ltd., Toronto	12,000	†7,000	S-C
Total	77,400	29,100	

QUEBEC

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
British-American Oil Co., Ltd., Montreal	12,000	7,500	S-C-A
Gen. Pet. Refineries, Pointe-aux Trembles*	300	.....	S
Imperial Oil, Ltd., Montreal	30,000	3,400	S-C-L-A
McColl-Frontenac Oil Co., Ltd., Montreal	16,000	†12,000	S-C
Shell Oil Co. of Canada, Ltd., Montreal	10,000	7,000	S-C
Total	68,300	29,900	

SASKATCHEWAN

British-American Oil Co., Ltd., Moose Jaw	4,000	2,000	S-C-A
Consumers Co-op Refs., Ltd., Regina	2,000	900	S-C
Diana Oil & Ref. Co., Lloydminster	250	.....	S-L-A
High-Way Refineries, Ltd., Moose Jaw	350	.....	S
High-Way Refineries, Ltd., Rosetown	350	.....	S
High-Way Refineries, Ltd., Saskatoon	400	.....	S
Imperial Oil, Ltd., Regina	10,500	3,200	S-C-A
Sterling Ref., Ltd., Yorkton*	750	250	S
Total	18,600	6,350	

REFINERIES IN MEXICO

Petroleos Mexicanos, Ciudad Madero	60,500	8,000	Comp.
Petroleos Mexicanos, Arbol Grande	23,000		S-L-W
Petroleos Mexicanos, Belle Vista	5,500	1,200	S-C
Petroleos Mexicanos, Mata Redonda	23,500	7,000	S-C
Petroleos Mexicanos, Poza Rica	7,500	.....	S
Petroleos Mexicanos, Minatitlan	32,000	.....	S-L
Petroleos Mexicanos, Mexico City*	19,500	.....	S
Petroleos Mexicanos, Salamanca†	.....	.....	
Refinerias Mexico, Nuevo Laredo	330	.....	S
Refinerias Laredo, Nuevo Laredo	190	.....	S
Refineria Union, Monterrey	160	.....	S
Refineria del Norte, Cd. Juarez	1,000	.....	S
Total	173,180	16,200	

*Refinery being expanded January 1946.
†Under construction January 1946.

SHUTDOWN PLANTS IN CANADA

Abasand Oils, Ltd., Fort McMurray, Alta.	800	600	S-C-A
Lion Ref. Co., Calgary, Alta.	(*)	(*)	
Home Oil Distributors, Vancouver, B. C.	(*)	(*)	

*Capacities not reported.

SHUTDOWN PLANTS IN THE U.S.

CALIFORNIA

Company and plant location—	Crude oil cap. bbl.	Cracking cap. bbl.	Type of refinery
Fullerton Oil Co., Casmalia	2,500	.....	S
Olympic Refining Co., Long Beach	6,500	.....	S
Operators Oil & Ref. Co., Long Beach	5,000	.....	S
Richfield Oil Corp., Bell	10,000	4,500	S-C
Total	24,000	4,500	

COLORADO

Raven Oil & Ref. Co., Rangely	115	.....	S

KANSAS

Anco Ref. Co., Garnett	550	.....	S

LOUISIANA

Arkansas Fuel Oil Co., Bossier City	25,000	†11,500	S-C

MICHIGAN

Leonard Refineries, Inc., St. Louis	4,000	.....	S

MONTANA

Big Lake Oil Co., Lake Basin	80	.....	S
Carter Oil Co., Kalispell	1,000	.....	S
Gallatin Farmers Co., Belgrade	240	.....	S
Hunt, D. Eugene, Winnett	400	.....	S
North American Oil & Ref. Co., Chinook	300	.....	S
Ohio Oil Co., Lewiston	1,500	.....	S
Patterson, H. F., Ref. Co., Sweet Grass	800	.....	S
Petroleum Ref. Co., Shelby	1,000	.....	S
Sandgren & Nyhagen, Cut Bank	35	.....	S
Unity Pet. Corp., Kalispell	1,200	250	S-C
Walgren, C. E., Cut Bank	50	.....	S
Total	6,605	250	

OHIO

National Ref. Co., Findlay	9,200	†3,200	Comp.

OKLAHOMA

Associated Refineries, Inc., Duncan*	.....	17,000	C

TEXAS

Abercrombie, J. S., and Harrison Oil Co., Sweeney*	18,000	†4,700	S-C
Danciger Oil & Ref. Co., Longview	7,500	4,000	S-C
Humble Oil & Ref. Co., Ingleside	31,500	.....	S
Total	57,000	28,900	

WYOMING

Douglas Refinery, Douglas	80	.....	S

STATUS OF GOVERNMENT-OWNED SYNTHETIC-RUBBER PLANTS

Butadiene

Company, plant location and type—	Capacity short tons/year
Carbide & Carbon Chemical Corp., Institute, W. Va., alcohol†	80,000
Carbide & Carbon Chemical Corp., Louisville, Ky., alcohol†	60,000
Koppers, Inc., Kobuta, Pa., alcohol†	80,000
Total butadiene (alcohol)	220,000
Cities Service Co., Lake Charles, La., petroleum*	55,000
Humble Oil & Ref. Co., Baytown, Tex., petroleum*	30,000
Neches Butane Products Co., Port Neches, Tex., petroleum*	100,000
Shell Union Oil Corp., Los Angeles, Calif., petroleum*	55,000
Sinclair Rubber, Inc., Houston, Tex., petroleum*	50,000
Standard Oil Co. (N. J.), Baton Rouge, La., petroleum*	15,000
Phillips Pet. Co., Borger, Tex., petroleum*	45,000
Standard Oil Co. (Calif.), El Segundo, Calif., petroleum*	18,000
Sun Oil Co., Toledo, Ohio, petroleum*	15,000
So. Calif. Gas Co., Los Angeles, Calif., petroleum*	30,000
Total butadiene (petroleum)	413,000
Total butadiene	633,600

Styrene

Carbide & Carbon Chemical Corp., Institute, W. Va.†	25,000
Dow Chemical Co., Los Angeles, Calif.*	25,000
Dow Chemical Co., Velasco, Tex.*	50,000
Koppers Co., Kobuta, Pa.*	37,500
Monsanto Chemical Co., Texas City, Tex.*	50,000
Total styrene	187,500

GR-S (Butadiene-Styrene)

Company, plant location and type—	Capacity short tons/year
Copolymer Corp., Baton Rouge, La.*	30,000
Firestone Tire & Rubber Co., Akron, Ohio*	30,000
Firestone Tire & Rubber Co., Lake Charles, La.*	60,000
B. F. Goodrich Co., Port Neches, Tex.*	60,000
B. F. Goodrich Co., Borger, Tex.*	45,000
B. F. Goodrich Co., Louisville, Ky.*	60,000
General Tire Co., Baytown, Tex.*	30,000
Goodyear Synthetic Rubber Corp., Akron, Ohio*	30,000
Goodyear Synthetic Rubber Corp., Houston, Tex.*	60,000
Goodyear Synthetic Rubber Corp., Los Angeles, Calif.*	60,000
U. S. Rubber Co., Los Angeles, Calif.*	30,000
U. S. Rubber Co., Naugatuck, Conn.*	30,000
U. S. Rubber Co., Institute, W. Va.*	90,000
National Synthetic Rubber Corp., Louisville, Ky.*	30,000
Total GR-S	705,000

GR-I (Butyl)

Standard Oil Co. (N. J.), Baton Rouge, La.*	38,000
Humble Oil & Ref. Co., Baytown, Tex.*	30,000
Total GR-I	68,000

GR-M (Neoprene)

E. I. du Pont de Nemours Co., Louisville, Ky.*	60,000
Total synthetic rubber, long tons per year	833,000

Furfural

Q. O. Chemical Co.*	12,000

Carbon Black

United Carbon Co., Odessa, Tex.,* lb. per year	41,000,000

*Operating. †Shutdown (standby).

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To Minimize Fire Hazard.

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CATALYTIC AND ASSOCIATED UNITS

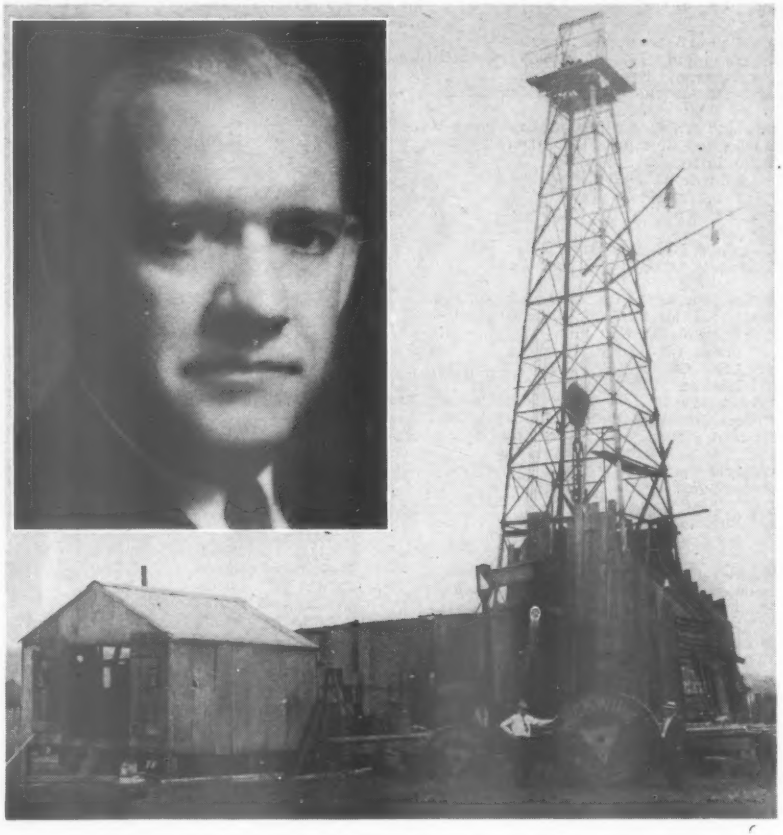
Company and plant location—	Catalytic cracking Type	Catalytic cracking Charging cap. (B./D.)	Alkylation Type	Alkylation Production (B./D.)	Isomerization Production (B./D.)	Other Units * Type and production
Abercrombie, J. C., Co., and Harrison Oil Co., Sweeney, Tex.*¶	Fluid	13,000	HF	4,000	1,500	
Anderson-Prichard Ref. Co., Cyril, Okla.	.....	.....	.....	.....	.....	Feed preparation, gas concentration, 320 bbl. per day§
Ashland Oil & Ref. Co., Catlettsburg, Ky.	T.C.C.	§10,000	HF	§3,000	§1,300	
Associated Refineries, Inc., Duncan, Okla.*¶	Fluid	10,000	HF	3,000	1,300	
Atlantic Ref. Co., The:						
Philadelphia, Pa.	Fluid	15,000	HF	2,400	.....	
Port Arthur, Tex.	Fluid	15,000	HF	2,400	.....	
Bay Pet. Corp., Denver, Colo.	.....	.....	.....	.....	.....	Feed preparation, gas concentration, 130 bbl. per day§
Champlin Ref. Co., Enid, Okla.	.....	.....	HF	‡§2,300	‡§1,450	
Chicago Corp., Agua Dulce, Tex.	.....	.....	.....	.....	.....	Feed preparation, gas concentration‡§
Cities Service Oil Co., East Chicago, Ind.	.....	.....	H_2SO_4	‡§2,800	‡§1,000	
Cities Service Ref. Co., Lake Charles, La.	Fluid	51,000	HF	8,000	1,500	
Continental Oil Co.:						
Ponca City, Okla.	T.C.C.	§20,000	HF	‡§3,600	‡§1,000	
Lake Charles, La.	.....	.....	H_2SO_4	680	.....	Reversion 2,500 bbl. per day
Wichita Falls, Tex.	.....	.....	H_2SO_4	700	.....	
Cooperative Refinery Assn., Coffeyville, Kans.	Fluid	‡§3,900	HF	‡§605	‡§230	
Crown Central Pet. Corp., Houston, Tex.	T.C.C.	‡§10,000	HF	‡§3,500	‡§1,300	
Eastern States Pet. Co., Houston, Tex.	Fluid	§6,000	HF	‡§1,600	‡§600	
Frontier Ref. Co., Cheyenne, Wyo.	Fluid	§2,700	HF	‡§1,100	‡§450	
General Pet. Corp. of Calif., Torrance, Calif.	T.C.C.	40,000	HF	5,000	.....	Delayed coking†
Great Southern Corp.	.....	.....	HF	‡§1,500	.....	Dehydrogenation
Gulf Oil Corp.:						
Philadelphia, Pa.	Fluid†	18,000	H_2SO_4	2,400	.....	
Port Arthur, Tex.	Houdry and T.C.C.	34,000	H_2SO_4	3,200	.....	
Humble Oil & Ref. Co., Baytown, Tex.	Fluid	46,800	H_2SO_4	6,500	.....	Hydrogenation 13,000 bbl./d.‡§
Leonard Refineries, Inc., Alma, Mich.	T.C.C.†	3,000	.....	.....	.....	
Magnolia Pet. Co., Beaumont, Tex.	Houdry and T.C.C.	58,000	H_2SO_4	2,300	.....	
Mohawk Pet. Corp., Bakersfield, Calif.	.....	.....	HF	‡§1,000	‡§450	
Pan American Ref. Corp., Texas City, Tex.	Fluid	23,000	H_2SO_4	3,700	‡§700	Cat. hydroforming 6,800 bbl /d.
Pennzoil Co., Oil City, Pa.	.....	.....	HF	‡§1,500	.....	
Phillips Pet. Co., Borger, Tex.	Cycloversion	10,000	HF	.....	.....	
Premier Oil Co. of Texas, Longview, Tex.	.....	.....	HF	‡§2,200	‡§750	Dehydrogenation
Pure Oil Co., Toledo, Ohio	.....	.....	H_2SO_4	‡§1,330	.....	Hydroforming
Republic Oil Ref. Co., Texas City, Tex.	Fluid	13,000	HF	‡§2,000	.....	
Richfield Oil Corp., Watson, Calif.	T.C.C.	23,000	H_2SO_4	5,200	.....	
Root Pet. Co., El Dorado, Ark.	Fluid	§5,000	HF	§1,500	‡§450	
Shell Oil Co.:						
Watson, Calif.	Fluid	15,000	H_2SO_4	6,500	2,800	
Martinez, Calif.	.....	.....	H_2SO_4	750	.....	
Wood River, Ill.	Fluid	31,000	H_2SO_4	4,500	1,500	Hydrogenation 400 bbl./day
Houston, Tex.	Shell†	15,000	H_2SO_4	2,500	1,000	Hydrogenation 300 bbl./day
Norco, La.	.....	.....	H_2SO_4	700	.....	
Shell Oil Co. of Canada, Montreal, Que.	.....	.....	H_2SO_4	1,600	650	
Sinclair Ref. Co.:						
East Chicago, Ind.	.....	.....	H_2SO_4	750	.....	
Houston, Tex.	Houdry and T.C.C.	20,000	H_2SO_4	1,800	.....	
Corpus Christi, Tex.	Houdry	10,000	HF	1,700	300	
Sinclair, Wyo.	Fluid	6,000	H_2SO_4	1,700	.....	
Socony-Vacuum Oil Co.:						
Augusta, Kans.	Houdry	9,000	HF	855	.....	
Brooklyn, N. Y.	Houdry	9,000	.....	.....	.....	
Buffalo, N. Y.	Houdry	9,000	.....	.....	.....	
East Chicago, Ind.	Houdry	7,200	.....	.....	.....	
East St. Louis, Ill.	Houdry and T.C.C.	18,000	HF	1,670	.....	
Paulsboro, N. J.	Houdry and T.C.C.	19,000	HF	1,670	.....	
Trenton, Mich.	Houdry	10,000	.....	.....	.....	
Southport Pet. Co., Texas City, Tex.	Houdry	‡§13,000	HF	‡§1,600	.....	
Standard Oil Co. (Calif.):						
El Segundo, Calif.	Houdry	7,450	H_2SO_4	4,250	750	
Richmond, Calif.	T.C.C.	§14,000	H_2SO_4	§2,300	§1,400	Hydrogenation 2,000 bbl./day
Standard Oil Co. (Ind.):						
Whiting, Ind.	Fluid†	20,000	H_2SO_4	2,900	4,500	Hydroforming 8,500 bbl./day
Wood River, Ill.	Fluid	11,000	H_2SO_4	3,649	1,460	Hydrogenation 1,000 bbl./day
Sugar Creek, Mo.	Fluid	.....	.....	.....	.....	
Standard Oil Co. (N. J.), Baton Rouge, La.	.....	.....	.....	.....	.....	Hydrogenation 11,000 bbl./d.‡§
Standard Oil Co. (Ohio):						
Cleveland, Ohio	Houdry	20,000	.....	.....	.....	
Toledo, Ohio	.....	.....	H_2SO_4	1,200	.....	
Sun Oil Co.:						
Marcus Hook, Pa.	Houdry	84,500	HF	4,900	.....	
Toledo, Ohio	Houdry	14,500	.....	.....	.....	
Texas Co., The:						
Lockport, Ill.	Fluid	20,000	H_2SO_4	2,000	1,000	
Los Angeles, Calif.	Fluid	15,000	H_2SO_4	3,800	.....	
Port Arthur, Tex.	Houdry and Fluid	49,000	H_2SO_4	12,000	2,800	
Tide Water Associated Oil Co.:						
Avon, Calif.	Fluid	17,300	H_2SO_4	5,000	2,510	
Bayonne, N. J.	Houdry and T.C.C.	25,000	.....	.....	.....	
Union Oil Co. of California:						
Oleum, Calif.	.....	.....	.....	.....	.....	Hydroforming 6,500 bbl./day
Wilmington, Calif.	T.C.C.	4,500	H_2SO_4	3,500	1,000	Reversion 6,500 bbl./day
Utah Oil Ref. Co., Salt Lake City, Utah	Fluid§	8,500	H_2SO_4	§3,000	‡§1,000	
Wilshire Oil Co., Norwalk, Calif.	Fluid‡§	4,000	HF	‡§1,750	‡§1,000	

FOOTNOTES

*Refinery not operating January 1946. †Under construction January 1946. ‡Unit not operating February 1946. §Units government-owned as of January 1946. ¶Aviation fuel plants government-owned as of January 1946.

World's Deepest Cable-Tool Test Is Completed

*by John T. Galey**



View of rig which drilled the 10,096-ft. deep test in Butler County, Pennsylvania. Inset: Charles E. Bennett, president, The Manufacturers Light & Heat Co., which firm drilled the deep test here described

THE deepest cable-tool hole in the world, so far as can be ascertained, has recently been completed by Manufacturers Light and Heat Co. on the Jesse G. Hockenberry farm, Mercer Township, Butler County, Pennsylvania. This wildcat was abandoned, after it showed considerable salt water, at 10,096 ft. in what is considered to be an Upper Cambrian sand. Stratigraphically, the test is the deepest yet drilled in Western Pennsylvania, Eastern Ohio, or West Virginia.

Foley & Fox of Washington, Pa., veteran deep-drilling contractors, completed their work in the remarkable total elapsed time of 312 days. This does not include shutdown time (the well was shut down awaiting orders from November 21 to April 5 and was usually shut down over Sunday), but does include all other time consumed by drilling, cementing, fishing, repairing, running casing and spooling, splicing, and changing lines.

Geology

The principal geological markers encountered are the Vanport limestone (Pennsylvanian) at a depth of 28 to 38 ft.; the Berea sand (Mississippian), 728-41 ft.; Tully limestone (Devonian), 4,482-4,532 ft.; Onondaga limestone (Lower Devonian), 4,702-4,828 ft.; Oriskany sand (Lower Devonian), 4,828-41 ft.; Lockport dolomite (Silurian), 5,935-6,185 ft.; Medina sands (Silurian), 6,453-633 ft.; Trenton limestone (Ordovician), 8,812-9,553 ft; Beekmantown (?) (Cambrian) dolomite, 9,553-10,074 ft.; Upper Cambrian (?) sand 10,074-96 ft. Elevation is 1,306 ft. above sea level.

The deviation from the vertical in the hole is shown by the pictures taken after completion by Sperry Sun Wells Surveying Co.

Depth (ft.)	Deviation from vertical degrees	Direction
200	⅝	S 40° E
720	⅝	S 10° W (?)
6,800	2	N 83° W
7,776	⅜	S 70° W
7,976	⅜	S 75° W
8,610	1½	N 73° W
8,810	2	N 70° W
9,600	½	S 50° W
9,800	¾	N 30° E
10,053	1½	S 85° E

Tools were bypassed in the hole at 7,876, 8,710, and 9,704 ft. and did not seroiusly alter the direction.

There were several shows of gas, one of which was in the Trenton at 9,505-10 ft. and another in dolomite, probably the Beekmantown, at a depth of 9,746-71 ft. These shows were acidized after plugging back, but were not found to be commercially productive.

Casing

Casing requirements were surprisingly small on account of the relatively few water-bearing horizons encountered and the contractor's ability to control the caving formations by cementing. Actually all of the casing used consisted of 151 ft. of 13-in., 542 ft. of 10-in., 1,557 ft. of 8¼-in., and 6,710 ft. of 7-in. The latter string, which was extreme line, had 1,000 ft. of N-80 on the bottom and the remainder above of J-55. There was no casing run below this latter point. However, the wall of the hole was frequently cemented to prevent caving. Ordinarily 10 to 15 sacks of neat cement mixed to the consistency of thick pea soup was poured down the hole every Saturday night before shutting down. A half hour later the cement which had reached bottom was bailed from the hole.

Rig

The drilling rig, with the exception of a few refinements, was the sort usually employed in most deep-drilling operations in the Appalachian area. Derrick was a standard Lee C. Moore 84-ft. with dead-weight test of 435,000 lb., equipped with steel walking beam, calf wheels, 12-ft. band wheel, and two 14-in. brakes on the bull wheels. A special spool was put on the bull wheels to facilitate even coiling of the drilling line. The latter has been found to effect substantial saving in drilling-line wear. A standard 10,000-ft. O.C.S. chain-driven sand reel completed the rig.

The drilling motor was a Riise 170-

*Independent operator, Pittsburgh.

J. A. Fox, of Foley & Fox, drilling contractors; Clarence Sweeny, superintendent, Carnegie Gas Co.; C. J. McMahon, superintendent of production, Manufacturers Light & Heat Co.; Don S. Keenan, president, Carnegie Gas Co., and E. J. Egan, vice president and general manager, Manufacturers Light & Heat Co.

hp. equipped with a high, low, and reverse gear. From the top of the hole to 4,000 ft. a 28-in. pulley was used on this motor. This was changed to a 25-in. at 5,000 ft. and to a 20-in. at 6,500 ft. in order to obtain the power necessary to swing the tools at a lower stroke per minute. Then at 8,500 ft. the pulley was further reduced to 18 in. so that at the total depth plenty of power was still available.

Tools

From a short distance below the point at which the 8¼-in. casing was set to the total depth, a swivel socket was employed. The stem which drilled the hole to 6,701 ft. was a 5¼-in. by 28-ft. bar with 4½-in. tool joints. The remainder of the hole was drilled with 4¼-in. by 25-ft. or 28-ft. bars and 3¾-in. tool joints. The tools used in the hole were furnished exclusively by Spang & Co.

Lines

Drilling lines are an important item in the total cost of such a hole as this. However, the service derived from the lines used was considered to be excellent. A new 9,000-ft. semipreformed 1-in. line was put on at a depth of 5,083 ft. This line carried the hole to 7,876 ft. where a new line of the same kind was put on. At 8,385 ft. additional line was spliced on the latter, but otherwise it was able to carry the hole to 8,825 ft. As will be noted below, this was a particularly difficult portion of the hole to drill. A new 12,000-ft. 1-in. semipreformed gray strand straight left lay line was used from 8,825 to 9,657 ft., at which point 4,000 ft. of ⅞-in. mild plough line was spliced on the bottom, for the purpose of not only lightening up the load, but also of removing from the hole the portion of the line which had been subjected to the greatest stress. However, at 9,916 ft. an entirely new line consisting of 9,000 ft. of 1-in. fully preformed 6 by 21 and 5,000 ft. of ⅞-in. of the same kind was put on. This latter line was specially made so as to have the same lay in the 1-in. and the ⅞-in. portions. All of the above lines, together with 9/16-in. sand lines which were used throughout, were furnished by Wickwire-Spencer Steel Co.

The major stress on the line, when drilling at great depths, appears to be at from 800 to 1,000 ft. below the surface. For this reason, while drilling the deeper portion of the hole, the lay in the line was carefully watched and measured daily at the depth mentioned above. When the lay was found to exceed 11½ in. at this depth, the line was no longer considered safe to run. On the 12,000-ft. 1-in. line put on at 8,825 ft., the lay increased from 9 in. at 8,848 ft. to 11¼ in. at 9,594 ft. When the 4,000 ft. of ⅞-in. line was spliced on this, the lay was only 9¼ in. at 9,657 ft. The lay remained practically the same until the tools were struck at 9,704 ft. After the line had been cut at the latter point, the tools drilled by and a depth of 9,815 ft. reached, the lay was 11 in.

Drilling Difficulties

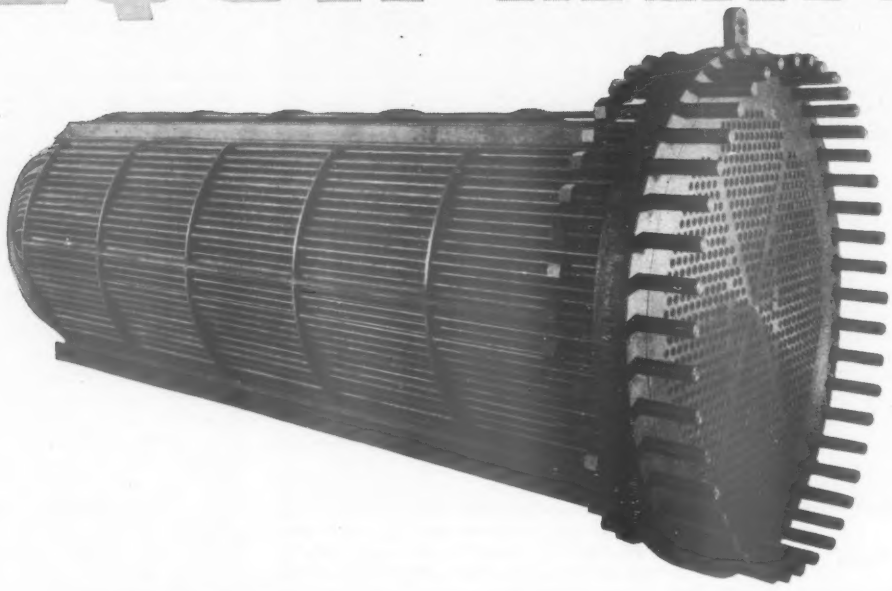
There were only two major obstacles to be overcome in drilling, and these were encountered commencing at a depth of 8,510 ft. and extending to 8,710 ft. where 11 gas pockets with various degrees of explosive force were struck. Some of these gas pockets would make gas at the rate of from 5 to 10 million cubic feet of gas per day, but would last only a matter of a few minutes. The gas pockets all occurred in soft shale and after each one, it was necessary to clean out the hole before new hole could be made. At a depth of 8,710 ft. in the last of three gas pockets the tools were stuck. They were jarred for 80 hours in hope of switching off the drilling line. Acid was dumped into the hole in an attempt to weaken the line and the tools again jarred. The process was repeated, and finally after 6 days of jarring, the line was broken 600 ft. above bottom. The tools and wire line left in the hole were cemented and drilling commenced at the top of the cement. While the cement was being drilled out gas pockets were found again, although only seven in number. However, a 300 to 400-ft. column of concentrated brine carried in the hole kept the gas pockets under control. Thirty-eight days' time was consumed before the depth of 8,710 ft. was again reached.

At 9,704 ft. another gas blowout was encountered which blew the tools

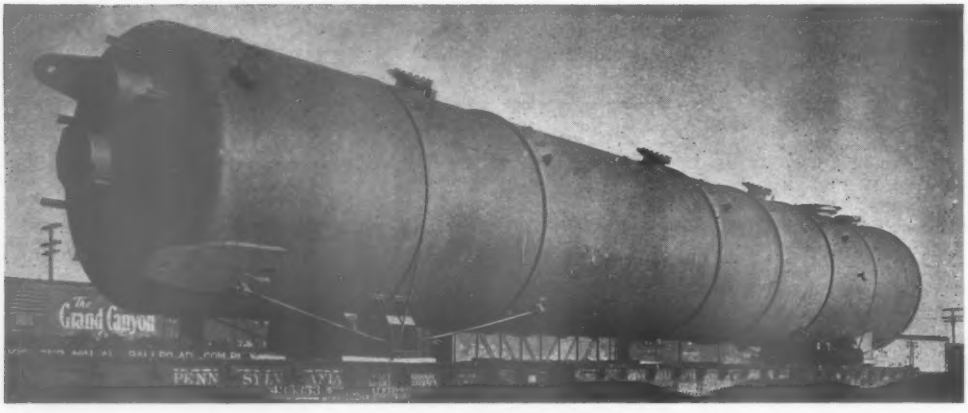
Drilling crew which drilled the well: Charlie Moore, driller; Griff Briggs, driller; Red Ward, tool dresser, and J. A. Fox

REFINERY EQUIPMENT

BUILT-TULSA TYPE RIGHT



IN WORLD-WIDE USE



Tulsa Boiler & Machinery Co.

TULSA 1, OKLAHOMA

EXPORT OFFICE: Room 1940, 30 Rockefeller Plaza, New York City 20, N. Y.

up the hole and wedged them so that they could not be removed. The difficult job of disconnecting the wire line from the stuck tools was solved here in the following manner. The tool was made and run under the supervision of Spang & Co.

A 4-ft. length of 4-in. bar made in halves longitudinally and slotted with 1½-in. internal opening was electrically welded on the drilling line. Water was passed through the opening during the welding operation to prevent damage to the line. This bar which had a 45° face at the top was then permitted to slide as far as it would go on the drilling line. A second bar 3 in. in diameter, weighing 150 lb., with length and internal diameter the same as the first was then welded around the drilling line. Tension was taken, and the second bar which had a rounded bottom was dropped. In 40 seconds the line was cut at 9,664 ft. by the action of the second bar on the first. Both parts of this line cutter were subsequently fished from the hole.

The stuck tools were cemented in the hole, a whipstock set at 9,664 ft. and drilling carried on to the total depth without mishap. Only 20 days were lost from the time the tools were stuck at the above mentioned point until new hole was being made below 9,704 ft.

The drilling difficulties encountered to 6,701 ft. were the ones ordinarily found in wells of the latter depth which penetrate the same section of rocks. A cave in the soft shale above the Onondaga limestone which occurred despite the use of a concentrated brine solution as drilling fluid was cemented with 50 sacks of neat cement. This was drilled out as soon as it would stand up. Squeezing in of the salt beds, which were encountered at approximately 5,250 ft., or some of their associated soft clays or shales was sufficient to stop the tools and kink the drilling line when running into the hole. The tools would often stick also when pulling out so that it was necessary to jar them through the squeezed-in portion of the hole.

The only additional difficulties came after new lines were put on at 7,876 and 8,825 ft. In the former case the stem broke at the weld and was quickly drilled by, and in the latter case the tools were lost, but were fished out in a few days.

Time

This Oriskany sand was reached in 64 days, and the Medina sands were drilled through in an additional 51 days. Footage drilled immediately above the Trenton limestone was as high as 40 ft. during a 12-hour tour, and in the Trenton limestone an average of more than a foot per hour was attained. At 10,000 ft., which is near the total depth, as much as 20 ft. in 24 hours was being drilled. Forty minutes were required to pull the tools from this depth and 10 minutes to run into the hole. The bailer was pulled in 25 and run in the hole in 5 minutes.

This remarkable feat has served not only to demonstrate the skill of the contractors and drillers, the performance of the equipment, and consequently the practicability of deep-cable-tool drilling in the Appalachian area, but also the comparatively low cost of such an operation. The contract was on a footage basis to 5,000 ft., and on a cost-plus basis to the total depth. The total cost of the well exclusive of casing, cement, and fuel was slightly under $81,000.

Acknowledgment

The writer gratefully acknowledges the kind assistance of J. A. Fox, Washington, Pa., one of the contractors, in the preparation of this report.

Portable Power Unit Useful in Refinery

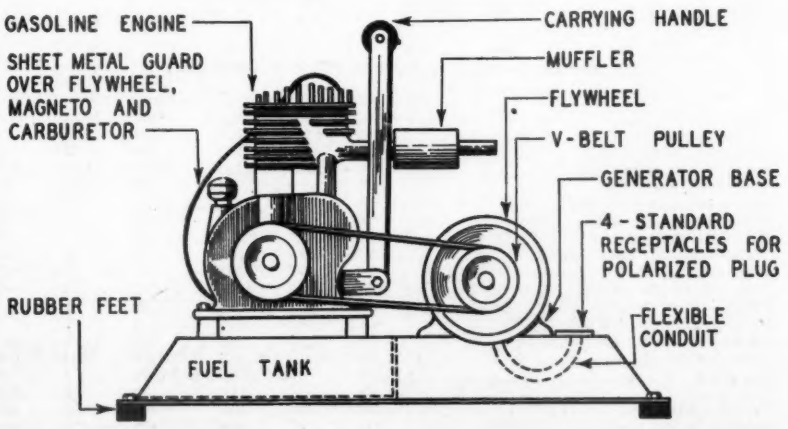
ELECTRICAL current for operating small tools such as hand drills and the like and for illumination is supplied by the portable gasoline-engine generator shown in the accompanying drawing. Small, compact and light in weight, the unit easily may be placed in a light truck or passenger car by one man. The unit has paid its cost of building many times in its first year of use. Initially built for the refinery's automobile mechanics to take out on night-time highway truck jobs for supplying illumination on the job, the unit has since been put on many uses within the refinery.

The gasoline engine used to drive the direct-current generator is one of the several popular makes that are cranked with a rope. Fuel for the engine is stored in a compartment in the base which is shop-made by welding 10 or 12-gage sheet steel. The base is provided with mounting brackets for the engine and generator and is equipped with rubber feet to reduce vibration. Also installed in the base is a terminal block which provides four circuits.

Final Balancing of Assembly

Positioning of the engine and generator on the base is important for maintaining balance about the pivoted lifting handle. Final balancing of the assembly may be done by increasing or decreasing the weight of the generator fly-wheel as the case demands. For a unit made with an ordinary engine and generator, the flywheel weight should run between 100 and 150 lb. per kw. based on generator rating. Exact weight of the flywheel for balancing the unit about the pivoted handle may be determined after all parts except the wheel have been assembled on the base. Diameter of the wheel should be as large as practicable and not less than 1.2 times the generator diameter. Its thickness will depend upon the relationship of its diameter to the weight required for balancing. The wheel should be carefully machined to insure reasonably good dynamic balance and the removal of metal for weight reduction should be made by turning a groove on one or both sides near its center. Ordinary steel plate, torch-cut to the desired diameter, will make a good wheel after it has been machine finished and provided with keyway and set screws.

In addition to serving as a counterbalance, the flywheel tends to smooth out speed variations of the engine and consequently more uniform generator performance is secured. Four 50-watt lamps or the equivalent in electrically powered tools may be operated with the small unit illustrated, which has a 2.2 amp., 115-volt, d.c. generator.



Extensive Water Analysis in Cycling Fields Yields Useful Information on Corrosion

AN extensive program of analysis of waters from cycling wells recently completed by the corrosion research project committee of the Natural Gasoline Association of America has yielded some significant information on the physical and chemical differences of corrosive and noncorrosive fields. While not as conclusive as first anticipated, the data indicate that appreciable quantities of iron and organic acids in well waters do not necessarily indicate a high rate of corrosion or that corrosion is present.

The work is part of the broad cycling-well corrosion studies of the N.G.A.A. corrosion committee of which T. S. Bacon, Lone Star Producing Co., Dallas, is chairman. Operating as a cooperatively financed project, the primary object of the committee is to determine the cause of corrosion in gas-condensate fields. This corrosion has been observed in tubing strings at depths up to 10,000 ft. and has been serious throughout tubing strings, well-head equipment, and flow lines from wells to cycling plants. Several theories have been suggested on the causes of this corrosion. One theory is that carbonic acid formed from reaction of the carbon dioxide content of the gas with the liquid water condensed from the gas might attack the steel equipment. Another theory was based on the fact that appreciable concentration of the lighter fatty acids, such as acetic and propionic acids, were found in water samples obtained from corroded wells. It also seems possible that the joint action of the carbonic acid and of the organic acids might be responsible for this serious corrosive attack.

In order to obtain factual information on the presence of the above acids, and on other chemical constituents of the waters produced from corroded wells, the N.G.A.A. instituted a sampling program of broad scope. Water samples were obtained from wells and fields of known corrosiveness and were carefully analyzed under the supervision of Prof. W. A. Cunningham, head of the department of chemical engineering, at University of Texas. As the committee realized that samples from corroded wells would give one side of the picture only, it arranged to have an approximately equal number of samples collected from wells that showed no corrosion. These samples from noncorroded wells were analyzed in the same way, following the same techniques, so that direct comparisons could be made between the chemical composition of water samples from corrosive wells and from noncorrosive wells.

Duplicate Samples Obtained

Duplicate samples were obtained from each well or field so that some indication of variation in chemical composition could be made. Samples were obtained from 14 corrosive fields, 10 noncorrosive fields, and 12 fields on which available operating information was insufficient to determine whether or not a corrosive condition existed. The maximum values, minimum values, and average values of the data obtained are shown in Table 1. It is interesting to note that the carbon dioxide content of the gas from the corrosive fields is definitely higher than that of the gas from the noncorrosive fields. However, it seems unlikely that this difference in carbon dioxide content as observed is sufficient in itself to explain the extreme differences in rates of corrosive attack. It is also interesting to observe that organic acid concentrations are very slightly higher in the corrosive fields than in the noncorrosive fields. It appears from this information that the presence of organic acids in the well-head water samples is not in itself an indication of the likelihood of serious corrosive attack.

Salt water is a well-known corrosive agent in the presence of oxygen. Gas wells do not contain oxygen and therefore the corrosiveness of the salt water is nominal. The amount of salt water in the well-head samples is indicated by the chloride content. It is noted from the data that many corrosive fields show very appreciable concentrations of salt water whereas many other corrosive fields show practically no salt in the well-head water samples. The noncorrosive fields also range in salt content from zero to extremely high concentrations as judged by the chloride content of the water samples.

Dissolved Iron Contents

The dissolved iron contents of the water samples of the corrosive fields were definitely higher than the dissolved iron contents of the water samples from the noncorrosive fields. However, some noncorrosive fields showed higher iron contents than some of the definitely corrosive fields. Therefore, it appears that iron content alone is not a satisfactory indication of the amount of corrosion that may be anticipated in any particular well or field.

The available data in their present form fail to show any significant chemical differences in the composition of water samples from corrosive fields as compared with water samples from noncorrosive fields. The data do indicate higher average pressures and higher average temperatures in the corrosive fields than in the noncorrosive fields. It is well known that acid attack of metals increases rapidly with increase in temperature and also that the effectiveness of inhibitors in preventing acid attack of metals decreases rapidly with rise in temperatures. Other work on this subject of high-pressure corrosion sponsored by N.G.A.A., and under the supervision of Dr. Norman Hackerman of University of Texas, has indicated the likelihood that the corrosive attack is an acid type of attack that is partly inhibited by some naturally occurring inhibitor in the corrosive wells and is substantially completely inhibited by the same naturally occurring inhibitor in noncorrosive wells.

TABLE 1—N.G.A.A. WATER-SURVEY SUMMARY

	Corrosive fields			Noncorrosive fields		
	Max.	Min.	Avg.	Max.	Min.	Avg.
Depth, ft.	13,200	4,050	8,077	7,200	2,197	4,840
Reservoir temp., °F.	250	157	207	190	76	142
Reservoir pressure, psi.	5,000	1,330	3,243	3,200	400	1,619
Well-head temp., °F.	170	100	134	130	72	95
Well-head pressure, psi.	4,000	1,110	2,454	2,640	250	1,198
Production rate, M.M.c.f./day	30	2.5	9.7	10	0.7	4.3
Distillate content, bbl./M.M.c.f.	70	2.5	27.8	26	0	8.2
Water content, bbl./M.M.c.f.	3.7	0.4	1.17	34	0	6.6
CO_2, vol. %	2.0	0.6	0.87	0.7	0	0.35
H_2S, grains/100 cu. ft.	0.08	0.0	0.001	0.2	0	0.05
pH (at atmos. press.)	6.5	4.5	5.4	7.2	4.1	5.8
Phenol. alkalinity, p.p.m. $CaCO_3$	0	0	0	0	0	0
M. O. alkalinity, p.p.m. $CaCO_3$	448	20	148	692	8	121
Total solids, p.p.m.	74,400	242	11,600	186,400	152	36,000
Cl, p.p.m.	39,200	0	5,780	95,500	0	18,100
SO_4, p.p.m.	104	0	21.0	70	8.5	29.9
Fe_2O_3, p.p.m.	1,280	160	439	441	57	185
Organic acids, p.p.m., C_2H_5COOH	812	49	222	405	0	156

QUESTIONS on TECHNOLOGY

by W. L. Nelson
Consulting Engineer

Simplified Flow Diagrams

Drying Natural Gas With Adsorbents

What is your idea of the best method of dehydrating natural gas? There is nothing unusual about our gas.—B. F. R.

Adsorbents such as activated alumina and fuller's earth are becoming increasingly useful as agents for the drying of natural gas or other gases and they are being applied to some extent in the drying of refinery liquids. They are sold under many trade names such as Porocel, Florite, Floridin, Ohmsted, Riverside, etc. In general, the materials are prepared or activated by the manufacturers by heating to a high temperature. Silica gel and anhydrous calcium sulfate have also been employed.

Although adsorption to the extent of 12-25 per cent is not uncommon with new materials, it is usual practice to design plants for the adsorption of only 4 to 7 per cent because the adsorbent gradually becomes fouled or plugged with impurities. Hydrogen sulfide in the presence of oxygen is particularly bad because free sulfur is deposited throughout the adsorbent. Small amounts of caustic soda or similar alkaline materials also rapidly destroy the efficiency of many earths. Cracked gases are also detrimental. With regular natural gases the adsorbent lasts for several years, and its cost is so small that more frequent replacements could in many instances be tolerated. The clay is usually supported at several points in the chamber to avoid channeling.

Obviously the adsorbents also tend to remove natural gasoline, distillate, and absorption oil from the gas, but these are displaced by moistures as more and more gas flows through the plant. As the content of adsorbed moisture increases, the dew point of the effluent natural gas increases somewhat as follows:

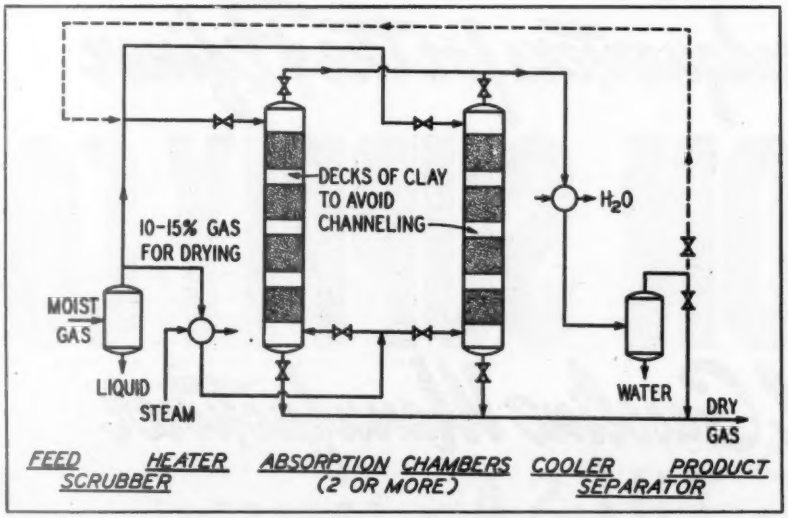
Adsorbed moisture, % by weight	Dew point
0	below —20
5	below —10
10	zero

Of course, each gas or incoming moisture content gives somewhat different results.

The method of operation may be understood from the simplified flow diagram on this page. One chamber (or a battery of them) is used to dry the main bulk of the gas while a smaller hot stream (10-15 per cent) of the gas is used to dry the moisture from a spent chamber (or battery of chambers). The small stream of hot gas is cooled after it leaves the chamber so that the main bulk of the moisture contained in it is condensed and collected in a receiver. If the outgoing gas must be exceedingly dry (or if the adsorbent is so old that it is ineffective), the small stream of somewhat wet gas may be recycled through an adsorbent chamber as indicated by the dotted line but the usual practice is simply to mix the two streams of gas. Some of the small stream of moist gas may be used as fuel for generating steam.

Regeneration is usually accomplished at 300°-400° F. which does not remove all of the moisture but is apparently the economic limit of temperature. Higher temperatures remove scarcely any more moisture and require an expenditure of heat to raise the temperature of the chamber whereas lower temperatures fail to remove enough moisture. Temperatures of even 600° F. are not detrimental to any of the common adsorbents excepting silica gel.

The chambers are sufficiently large to provide an "onstream" cycle of 12 to 24 hours. According to the excellent paper by Capell and Amero, "Dehydrating Liquids and Gases With Granular Adsorbents," The Oil and Gas Journal, page 37, June 18, 1942, the cross-sectional area of the chamber should be such that the velocity of the gas (based on the empty tower) is 20 to 60 ft. per minute.



Simplified flow diagram—dehydration of gases by adsorbents

Air in Natural Gas

We have a very rich natural gas. Is it satisfactory to add air to it to reduce its heating value to the regular value?—R. A. P.

From a general ethical standpoint it is not legitimate to sell air along with natural gas, nor is it wise to encourage a situation that in a moment of carelessness may cause a serious explosion. We have no record of anyone deliberately adding air to natural gas.

Nevertheless, air is added to gas in so-called butane-gas plants for small cities. In such plants liquid butane is purchased and vaporized, and since it has a heating value in excess of 3,000 B.t.u. per cubic foot, whereas most natural gas has a heating value only a little over 1,000, it is diluted with air so that it will exhibit combustion characteristics similar to regular gas. Pure butane gas would be so rich that special burner appliances would be necessary or at least all burners would have to be specially adjusted in order to handle it. For this reason it is accepted as good practice to dilute pure butane gas with about two volumes of air.

With regard to explosions, there is no need to worry except on those occasions when by chance too much air is added to the butane. The explosive limits of butane and most natural gas ranges from about 1.5 to 13 per cent hydrocarbon gas and hence any other mixtures will not be explosive.

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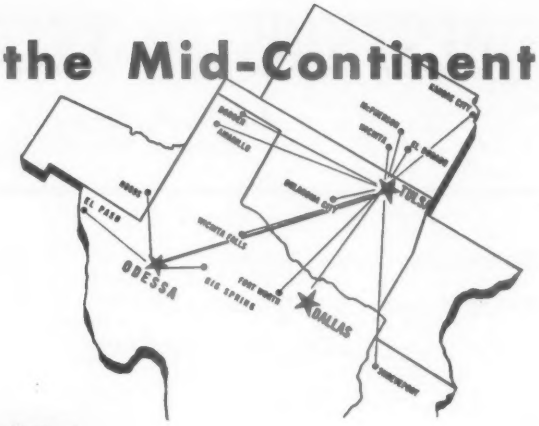

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Engineering Fundamentals

No. 228

A FEATURE OF THE OIL AND GAS JOURNAL

Explanation of Pinch-Out and Erosional Unconformity

MANY traps which cause accumulation of oil and gas occur in stratigraphic wedges which represent zones that show convergence by gradual thinning of their members and by successive dropping out of the members in periodical or irregular order, in effect causing a number of unconformable breaks. This is in contrast to stratigraphic zones abruptly cut off by angular unconformities.

Petroleum reservoirs associated with both of these conditions have become very important. However, certain difficulties in the interpretation of unconformity problems arise from the dual use of the term "unconformity" as a "surface of either erosion or nondeposition separating two groups of strata." An attempt is made in the following to explain diagrammatically the logical relations between stratigraphic wedge and unconformity conditions and the position of possible reservoir traps with respect to each. In the section (Fig. 1) the formations shown form three groups.

Upper Group L, constant thickness, continuous.

Middle Group M, converging and wedging out.

Lower Group N, constant thickness and truncated by erosion. Horizontally the section is divided into three segments:

Segment 1, normal stratigraphic sequence.

Segment 2, stratigraphic wedge of Group M.

Segment 3, Groups L and N meet at the erosional unconformity.

Note that in subsegment 2a, Group M shows thinning by convergence of its subzones but all markers can be traced, while in 2b individual members of Group M gradually drop out at an unconformity until the whole group is pinched out entirely. The possibility of differentiating subsegment 2a from 2b depends on the quality and density of the correlatable markers. In Segment 3, Group N does not go out by natural thinning; the break between Group M and N is definitely a plane of erosion, an erosional unconformity which is angular.

Segment 2 represents the logical intermediate stage of convergence between the normal regional stratigraphic succession in Segment 1 and conditions brought about by uplift and erosion in Segment 3. Under submerged marine conditions of deposition, as encountered in connection with petroleum deposits, the structure of Segment 2 results from the balancing of the rate of sedimentation and the rate of uplift. In the simple case shown on the sketch, the rate of uplift was greater during deposition of the stratigraphic members M-e and M-d, causing regression in sedimentation and smaller during deposition of the members M-b and M-a, causing transgression.

Depositional Unconformity

If the tectonic movements and deposition were in perfect balance, the interruption in the stratigraphic sequence in the Subsegment 2b would be due to nondeposition alone. However, due to exposure between the regression and transgression phases local erosion may have affected this depositional unconformity and ordinarily it is difficult to decide from subsurface data whether the updip edge of a bed that pinches out in a zone of convergence is the original margin or whether it is cut back by erosion.

Absence of basal conglomerates or basal detrital zones would be characteristic of unconformities developed under such conditions, since the rock fragments removed by erosive action in Subsegment 2b would rather be found scattered through the stratigraphic intervals in the adjoining Subsegment 2a where deposition was uninterrupted. Under the circumstances shown on the sketch, such material might be found in the M-c member of 2a.

The presence of traps under the foregoing conditions depends on the relative position of permeable and impermeable beds. As for the evaluation of possibilities for reservoirs located in Segment 2 of Fig. 1, the following may be considered. The M-a member must be impermeable to seal the wedge entirely in an updip direction and to provide favorable possibilities for traps in its lower permeable members. If M-a is permeable and M-b impermeable, only M-c and M-d are protected and suitably trapped if they are permeable. If M-c is the first impermeable member in the wedge, no favorable reservoir conditions will be found in the M group despite its wedge structure, unless sealing is effected by impermeable formation at the base of the L group. The latter condition is also required to produce traps in Segment 3.

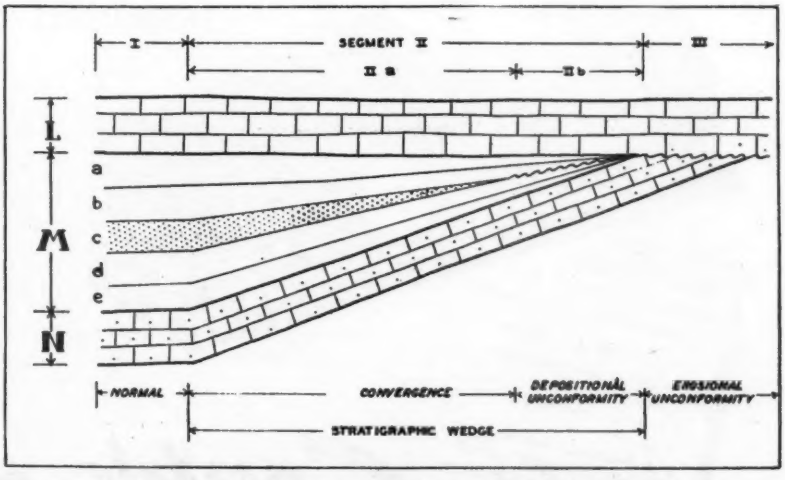

Fig. 1—Diagrammatic relation between the normal stratigraphic sequence, stratigraphic wedge, and unconformable conditions

Series prepared by Dr. O. Wilhelm, Shell Oil Co., Inc. (A. A. P. G. Bulletin Vol. 29, No. 11)

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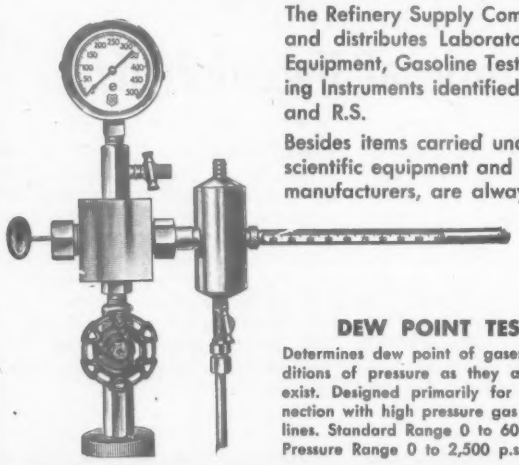

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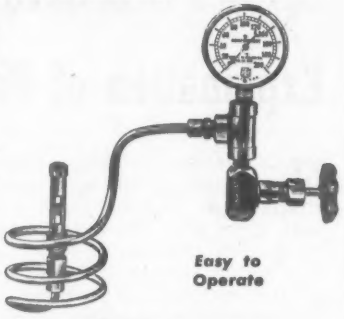

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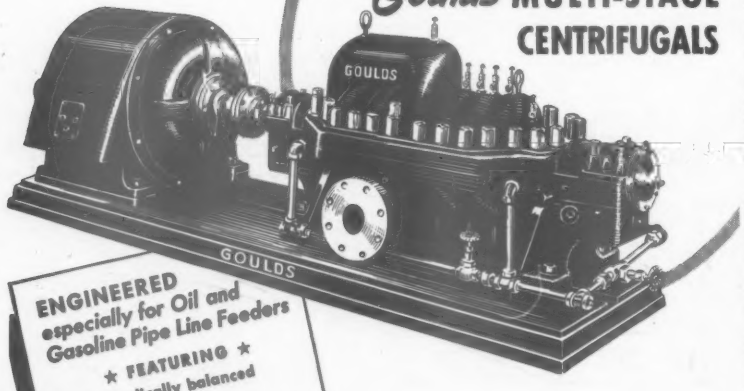

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Ethyl Asks Customers to Order Only Needed Lead

NEW YORK.—Stating that Ethyl Corp. has "no reason to believe that we will receive a sufficient allocation (of tetraethyl lead) from the Civilian Production Administration to supply the full requirements of our customers during the months ahead," Earle W. Webb, president, in a wire to all of Ethyl's refining licensees, appealed to customers not to place orders inconsistent with their immediate needs. Text of the wire, which was sent March 21 follows:

"For several months we have had many discussions with the people in Washington who are in charge of allocating metallic lead in attempting to secure sufficient tonnage to meet our customers' requirements for tetraethyl lead. Lately, representatives of the American Petroleum Institute, National Petroleum Association, and Western Petroleum Refiners Association have participated in these discussions. We feel we should inform you at this time that we have no reason to believe we will receive a sufficient allocation from the Civilian Production Administration to supply the full requirements of our customers during the months immediately ahead.

"We are hopeful, however, that the allocation will enable us to supply at least 80 per cent of such requirements. Meanwhile, we are doing our best to impress CPA with the gravity of the effect of such restrictions on the petroleum industry. We will proceed under the assumption that none of our customers will place orders inconsistent with this information. We will keep you advised regarding developments."

The wire was signed by Earle W. Webb, Ethyl's president.

Ethyl asked CPA for approximately 15,500 tons of lead for the second quarter, explaining that this would be the minimum amount required.

Eleven More Refineries Offered by Government

WASHINGTON.—Ten refineries for the production of high-octane gasoline or its components and one plant making toluene have been placed on the surplus property list by the War Assets Corp.

The latest group of refinery properties offered for sale or lease brings to 18 the number of plants placed on the market in recent weeks. Of the 11 plants, 6 are in Texas, 1 in Kansas and 2 each in California and Oklahoma. Details on the properties are available from the WAC office, Railroad Retirement Building, Washington 4.

Wartime operators of the plants, location, type of production, and capacity, where given, follow:

Pan American Refining Corp., Texas City, Tex., isopentane, 2,400 bbl. daily.

Humble Oil & Refining Co., Baytown, Tex., hydrogenation, 8,000 bbl. of feed charge daily.

Southport Petroleum Co. of Delaware, near Texas City, Tex., 100-octane gasoline, 3,000 bbl. daily.

Republic Oil Refining Co., near

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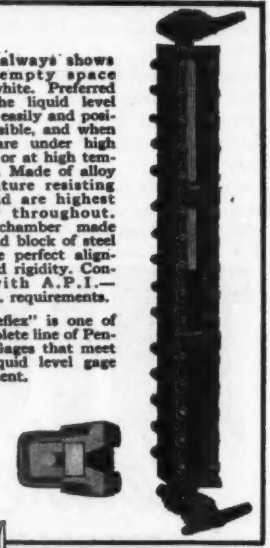

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Crown Central Petroleum Corp., Pasadena, Tex., 100-octane, 3,910 bbl. daily.

Cooperative Refinery Association, Coffeyville, Kans., 100-octane gasoline.

Continental Oil Co., Ponca City, Okla., toluene, 400 bbl. daily.

Continental Oil Co., Ponca City, Okla., 100-octane gasoline, 4,520 bbl. daily.

Wilshire Oil Co., Norwalk, Calif., 100-octane gasoline, 6,600 bbl. daily.

Mohawk Petroleum Corp., Bakersfield, Calif., 100-octane gasoline, 3,000 bbl. daily.

Award for Atomic Research Given to Whiting Group

CHICAGO.—The achievements of a group of scientists and technicians of Standard Oil Co. (Ind.) in wartime atomic bomb research were recognized in Whiting, Ind., last week.

More than 400 technical workers from the company's Whiting laboratories and refinery gathered for a dinner at which Dr. Robert E. Wilson, chairman of the board, passed on to the men responsible an award for chemical engineering achievement he had accepted in behalf of the company in New York in February. A. L. Conn, who was in direct charge of the atomic research at Whiting, accepted the award from Dr. Wilson.

Delivering the principal speech at the dinner, Dr. Harold C. Urey, Nobel prize winner and a leader in atomic bomb development, said that, in order to attain maximum development of atomic energy, "it is necessary that a considerable fraction of atomic energy information be made available to technically trained men of industry without having a considerable amount of the material published."

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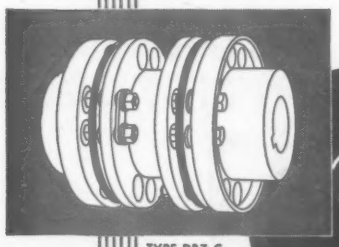

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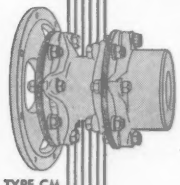

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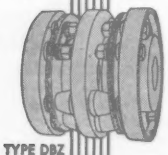

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Firm Starts Dismantling Corpus Christi Refinery

CORPUS CHRISTI.—Dismantling of the former Humble Oil & Refining Co. Ingleside refinery near here has been begun by Sampson Machinery & Supply Co. which recently purchased the 30,000-bbl. daily capacity plant.

The refinery, which turned out specialized products during the war and was closed down permanently by Humble a few months ago will be sold in lots and sections after dismantling. The job may take as long as 3 years to complete, according to Max Clairfield, Sampson company president. In addition to such equipment as valves, pipes, fittings, tanks, cracking units, the plant includes a power plant capable of supplying electricity to a city of 30,000.

Exports Drop to Fill 1945 Lubricating Oil Demand

WASHINGTON.—The United States filled its record-breaking 1945 lubricating oil demand by a heavy cut in exports, coupled with slightly increased production and a minor withdrawal from stocks.

War-stimulated need carried domestic demand for lubricating oil to 35,318,000 bbl. in 1945. This represented an increase of nearly 10 per cent over 1944's total of 32,183,000 bbl., and an increase of 43 per cent over 1940's total of 24,690,000 bbl.

Of the increase in domestic demand in 1945 over 1944, 73.3 per cent was filled by a reduction in exports from 8,889,000 bbl. in 1944 to 8,591,000 in 1945. Stocks showed only a decline from 7,815,000 bbl. to 7,773,000 bbl. in 1945.

Output of lubricating oil closely paralleled the increase in crude oil production. United States' crude production rose 1.98 per cent in 1945 over 1944. Domestic production of lubricating oil at 41,867,000 bbl. was 1.85 per cent over 1944. This increase, however, contributed only a relatively small part of the increased 1945 demand when compared to the cut in exports.

Natural Gas

Suttle Is New Managing Director of Gas Group

AUSTIN, Tex.—Robert R. Suttle, Austin consulting engineer, has been named new managing director of the Southern Gas Association by a special committee of the organization.

Suttle will handle affairs of the association from his present office in Austin until suitable quarters for the new association office in Dallas can be found. The new managing director formerly was an adviser to the college of business administration of the University of Texas. During the war, he served as a Navy lieutenant working in personnel relations and on several special industrial surveys.

Railroad Commission Moves To Enforce Use of Gas

AUSTIN., Tex. — The Texas Railroad Commission last week threatened a field shutdown to enforce its efforts to halt waste of casinghead gas.

At a hearing on gas conservation in Seeligson field, Jim Wells and Kleberg counties, Ernest O. Thompson, one of the commissioners, told Raymond H. Myers, representing Magnolia Petroleum Co., that "the commission intends to emphasize that we are serious about preventing gas waste, even to the point of shutting down fields."

Myers replied that "we think we have shown diligence in trying to promote conservation. Surely," he added, "the commission would not punitively shut down a field." Earlier, he outlined operators' plans to install natural gasoline processing equipment and said Tennessee Gas & Transmission Co. had offered to buy 30,000,000 cu. ft. daily of the residue gas subject to Federal Power Commission approval.

The commission has completed two of four meetings with operators throughout the state in an investigation of gas wastage. The Seelingson field hearing is the first of its specific nature called by the commission in its drive against gas waste, which an engineering survey estimated at 1,500,000,000 cu. ft. daily. The Seeligson field produces about 40,000,000 cu. ft. daily together with 23,000 bbl. of oil. Value of the gas now being flared in the field is placed at $1,150,000, and cost of the processing plant at $5,000,000.

The Seeligson field hearing results from the first of the investigative meetings held by the commission in Corpus Christi. The third was due to be held Thursday of this week in Midland.

The Railroad Commission last week also ordered operators in the Old Ocean field, Brazoria County, to appear April 17 and show cause why the field should not be shut down until arrangements are made to avoid flaring 12,286,000 cu. ft. of casinghead gas daily. "It looks like the days of gas flares in Texas are numbered," Thompson commented.

FPC to Hear Mexico Gas Export Cases April 1

WASHINGTON. — Two cases involving export of natural gas from Texas to Mexico will be heard here by the Federal Power Commission on April 1.

Reynosa Gas Pipe Line Co.'s request for authority to transport gas for ultimate consumption in Monterrey will come up for additional testimony on that date. FPC was asked by the Texas Railroad Commission for "further and new evidence" before a final decision is made. Two members of the Texas commission, Olin Culberson and Beauford Jester, have indicated they will continue to oppose the scheme.

The second case centers on an application of United Gas Pipe Line Co. for permission to continue selling and exporting natural gas from Texas to Mexico but at an increase in rates.

A.G.A. Committee to Study Economic Research Needs

NEW YORK.—A special committee on economic and market research needs is being organized by the American Gas Association under the chairmanship of E. H. Eacker, vice president of Boston Consolidated Gas Co.

The committee will review economic and market studies recently made or started by committees of the association, particularly the postwar planning committee, and determine the needs of the industry for further marketing and economics research, said Everett J. Boothby, A.G.A. president.

Need for Supervisor Training Stressed at A.G.A. Meeting

KANSAS CITY. — The need for foremen and supervisory training was emphasized at the meeting of the Midwest personnel conference of the American Gas Association which was held here recently.

Available material on the subject of foremen and supervisory training will be studied and a report made at the next conference which was set for June 6 here at the Phillips Hotel. Among other topics discussed at the meeting were industrial relations problems concerning the return to the 40-hour week. C. C. Jolley, personnel director of Natural Gas Pipe Line Co. of America, is chairman of the conference.

Flare Elimination Effected By Shell Oil in Louisiana

BATON ROUGE, La.—Utilization of substantial amounts of previously flared gas has been reported by Shell Oil Co., Inc., to the Louisiana Conservation Commission.

The company is now collecting 100,000,000 cu. ft. of gas in the Chalkley field and will soon begin utilization in several other fields, E. N. Van Duzee, division manager in Lake Charles for the company, reported to Joseph L. McHugh, conservation commissioner. A high-pressure gathering system is now operating in the Chalkley field and the company is proceeding with plans to install compressors against the time when wells will not flow against gathering-line pressure.

Operation of a similar gathering system in Gibson field awaits a shipment of meters, Van Duzee said. Definite plans also have been made for flare elimination in the La Pice and St. Gabriel fields.

Well Pipe Corrosion To Be Investigated

AUSTIN.—Ways of reducing corrosion in gas wells will be studied by a full-time research worker who will be placed on the University of Texas staff July 1 under a fellowship financed by the Natural Gasoline Association of America.

Dr. Normal Hackerman, university official, will select the recipient of the fellowship from graduate students in chemistry or chemical engineering at the university. The association offered a fellowship for investigation of the corrosion problem last year and is continuing with a larger contribution for the year beginning July 1.

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OKLAHOMA CONTRACTING COMPANY

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TOPS FOR
Main Line and Field Line } DITCHING
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PIPE LINES

Russia Reported Planning Pipe Line to Balkan Area

NEW YORK.—Russia's struggle for petroleum sufficiency is reflected in reports reaching here of Soviet plans for an oil pipe line to the Balkans and in the official Russian announcement of a production goal of 35,000,000 tons (254,310,000 bbl.) by 1950.

The pipe line Russia is reported to be considering would pull production in Rumania, and possibly Hungary, within the prewar Soviet borders. Pipe for the project already has been ordered in the United States, according to some sources.

At the present time, Russia is taking a large amount of the estimated 200,000 bbl. daily being produced on the European continent, practically all in the eastern area which is under Russian domination.

The production goal of 35,000,000 tons was included in a general statement of objectives of Russia's new 5-year plan which was adopted unanimously by the Supreme Soviet. In a mid-February speech, Stalin called on his people for huge production increases, setting ultimate oil output at 60,000,000 tons (435,000,000 bbl.) annually.

The Statemen's Yearbook in London recently placed Soviet oil production in 1941 at 38,000,000 tons (275,500,000 bbl.) but considerable productive capacity was destroyed during the German invasion of the country. Other sources estimate 1945 production in Russia at 25,000,000 tons (181,250,000 bbl.)

Permit Sought to Operate Warbuilt Gas Facilities

SHREVEPORT. — Officials of Arkansas Louisiana Gas Co. were to present their case for authority to operate permanently warbuilt facilities costing more than $3,500,000 in a hearing before the Federal Power Commission this week in Washington.

The company also is asking permission to construct additional facilities at an approximate cost of $530,000 to remove a portion of two 4-in. lines near Little Rock which are no longer in use. The permanent certificates requested cover 36 miles of pipe line from Lisbon field in Louisiana to El Dorado, Ark., and then to the Ozark Ordnance Plant; 6 miles of line built to supply a Naval ordnance plant in Ouachita County, Arkansas, and the company's "L" system which was built to supply gas to Arkansas war plants. The company proposes to use the "L" system to service a new Arkansas Power & Light Co. plant near North Little Rock, to maintain adequate service in Little Rock itself, and to service properties of Aluminum Ore Co. and Dulin Bauxite Co.

Sinclair Refining Plans Columbus-Detroit Line

NEW YORK.—A 6-in. products line will be laid for Sinclair Refining Co. from Toledo to Columbus, Ohio, and from Toledo to Detroit.

The company has asked bids for the construction. About 170 miles of pipe will be required. A two-way pumping station will be installed at Toledo to give the line a capacity of about 15,000 bbl. of gasoline daily in each direction.

The new line will tie into the company products trunk now operating

THESE SELSYN MOTORS

are available at much less than production cost! Take advantage of this opportunity to purchase from stock. Selsyn Motors have many applications, from indicating the angle of bridges and lock gates, levels of liquids, and direction and speed of wind, to communicating the volume of gases in tanks many miles distant. Made with three-pole, three-phase wound stators and two-pole rotors with winding for connection to single phase A.C. Designed for use on 115 volts, 400 cycles A.C., for experimental purposes it will operate on 15 to 21 volts, 60 cycles A.C. and on other frequencies. The estimated torque gradient in ampere degrees is .05, meaning the in.-oz. per degree measured between two identical machines. The excitation is .75 nominal amperes, and 8.2 nominal watts. No. G670 Selsyn Motor, $7.50 each ($6.75 in lots of 4—$6.37 in lots of 8—$6.00 in lots of 12).

CENTRAL SCIENTIFIC CO.
1700 Irving Park Road, Chicago 13, Ill.

from its East Chicago refinery to Toledo. Pipe has been contracted for, and delivery is expected to begin in April. Terminal sites, which will provide for distribution facilities in both Detroit and Columbus, have been purchased. Complete rights-of-way for the line also have been acquired.

Gulf Refining Co. Makes Perry a Vice President

HOUSTON.—N. H. Perry, for 27 years general superintendent of pipe lines of Gulf Refinng Co., has been elected a vice president succeeding E. C. Kincade who died several weeks ago.

After joining the Gulf organization in 1906 as a pumping station fireman, Perry progressively became engineer and chief engineer at Lufkin. In 1914, he was made pipe line superintendent at Tampico, Mexico, and since August 1919 has been general superintendent of pipe lines at Houston.

Panhandle Eastern Plans New Loop Construction

WASHINGTON.—Panhandle Eastern Pipe Line Co. is asking authority from the Federal Power Commission for loop line construction designed to boost the capacity of its system by 90,000,000 cu. ft. of natural gas daily.

A company representative said the proposed lines would be a step toward completing a third line similar to the two the company already operates from the Hugoton field to the Detroit area. The application to FPC said the increased capacity is necessary to serve communities in Texas, Oklahoma, Kansas, Missouri, Illinois, Indiana, Ohio, and Michigan. The company also is planning to continue its wartime service of gas to New York and Pennsylvania.

Pipe Lines Planned If Barge Rates Increase

NEW YORK.—The possibility that pipe lines will supplant present barge movement of oil products in New York and New England was cited here during an arbitration board hearing on towboat workers' wage and hour demands.

Robert B. Michell, Jr., vice president of Oil Transfer Corp., told the three members of the arbitration board that pipe lines would be constructed in the area to eliminate moving oil by water if present barge rates are increased.

He mentioned pipe lines from New Haven to Hartford, Conn.; from Albany to Schenectady, Utica, Rome, and Syracuse, N. Y.; from Rensselaer, N. Y., to Utica, Rome, and Syracuse; and from Rensselaer to Burlington, Vt. Moreover, he continued, plans, specifications, and estimates already have been obtained for two of the lines. An increase in barge rates is foreseen if wages are raised.

A.P.I. Transport Division Sets Up Pipe-Line Group

NEW YORK.—The American Petroleum Institute has set up a committee to study the industry's pipe line problems as a part of its newly organized division of transportation.

James E. Moss, division director, listed questions likely to occupy the time of the committee as: Interstate Commerce Commission valuation work; completion of meter code; and protection of pipe lines against corrosion and electrolysis.

U. S. Asked to Keep Lines

COLUMBUS, Ohio.—The Government was asked to hold the big-inch lines for any future national emergency instead of disrupting the present oil transportation system by their sale in a resolution passed by the Ohio Petroleum Marketers Association at its recent convention here. Both resolutions were offered by Hubert B. Fuller, Cleveland, general counsel of the association, and adopted after several days of discussion by the directors.

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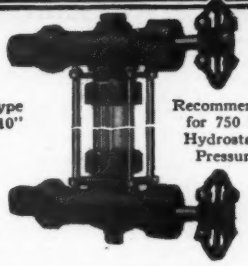
PENBERTHY

DROP FORGED STEEL

LIQUID LEVEL GAGES



Type "10"

Recommended for 750 lb. Hydrostatic Pressure

Steel construction throughout with stainless steel interior trim. Automatic shut-off is positive and instantaneous; stainless steel balls shut off the flow of liquid when glass breaks. Heavy duty stuffing boxes, union connections, offset construction facilitate cleaning and simplify glass replacement. Conform with A.P.I.—A.S.M.E. requirements.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

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STATISTICS and

WEEKLY WELL COMPLETIONS . . . WEEK ENDED MARCH 23, 1946

	Total of all wells					Cum. to date		Wildcat completions and discoveries					Cumulative total, 1946				
	Comp.	Oil	Gas	Dry	Footage	1946	1945	Oil	Dist.	Gas	Dry	Total	Oil	Dist.	Gas	Dry	Total
New York	27	14	1	*12	47,153	349	240	0	0	0	0	0	0	0	0	0	0
Pennsylvania	63	33	2	†28	94,251	942	789	0	0	0	0	0	0	0	0	0	0
West Virginia	16	4	10	2	40,678	154	172	0	0	0	0	0	0	0	0	0	0
Ohio	21	7	9	5	55,178	239	163	0	0	2	1	3	1	0	7	11	19
Indiana	9	7	0	2	17,402	65	40	1	0	0	0	1	1	0	0	6	7
Kentucky	5	2	1	2	13,707	93	84	0	0	0	2	2	1	0	0	14	15
Illinois	35	19	0	16	88,210	426	370	0	0	0	5	5	9	0	0	72	81
Michigan	10	4	1	5	22,822	148	166	0	0	0	3	3	3	0	0	49	52
Kansas	35	21	5	9	117,526	468	338	1	0	0	2	3	6	0	1	53	60
Neb., Mo., Iowa	0	0	0	0	0	4	11	0	0	0	0	0	0	0	0	2	2
Oklahoma	40	22	3	15	143,044	548	522	1	0	0	6	7	17	0	9	75	101
Texas	202	120	12	70	329,285	1,746	1,570	5	2	0	38	45	33	5	5	265	308
North Central	68	32	2	34	171,482	600	434	1	0	0	19	20	11	0	0	98	109
West	63	53	0	10	268,175	374	418	0	0	0	6	6	7	0	0	45	52
Panhandle	8	1	5	2	24,430	86	125	0	0	0	0	0	0	0	0	2	2
Eastern	20	12	4	4	113,966	167	71	1	0	0	3	4	2	0	1	26	29
Gulf Coast	29	18	1	10	196,772	398	378	2	1	0	5	8	9	3	2	58	72
Southwest	14	4	0	10	54,460	121	144	1	1	0	5	7	4	2	2	36	44
Louisiana	16	8	0	8	83,410	278	208	0	0	0	5	5	13	2	1	34	50
Northern	13	7	0	6	60,769	143	63	0	0	0	4	4	2	0	0	21	23
Southern	3	1	0	2	22,641	135	145	0	0	0	1	1	11	2	1	13	27
Arkansas	0	0	0	0	0	37	28	0	0	0	0	0	2	0	0	6	8
Mississippi	4	1	1	2	33,307	54	72	0	0	1	2	3	1	0	1	15	17
Southeastern States	0	0	0	0	0	11	7	0	0	0	0	0	0	0	0	10	10
Montana	3	1	0	2	6,141	55	63	0	0	0	0	0	2	0	0	3	5
Wyoming	4	4	0	0	18,465	46	47	0	0	0	0	0	5	0	2	16	23
Colorado	3	2	0	1	19,841	24	7	0	0	0	1	1	1	0	0	4	5
New Mexico	6	5	0	1	20,569	88	114	1	0	0	0	1	2	0	0	7	9
California	32	25	0	7	136,428	404	532	1	0	0	4	5	4	0	2	47	53
Utah	0	0	0	0	0	2	1	0	0	0	0	0	1	0	0	1	2
Total United States	531	299	45	187	1,787,417	6,181	5,543	10	2	3	69	84	102	7	28	690	827
Total previous week	541	304	48	189	1,823,384	5,650	5,066	10	3	2	64	79	92	5	25	621	743
Total March 24, 1945	477	270	37	170	1,729,486	5,543	4,300	11	0	3	57	71	146	3	33	722	904

Service wells included: *12, †28.

MARKET QUOTATIONS

(Quotations on other products than those shown here furnished on request. Quotations are f.o.b. plant in tank cars and in cents per gal. as of last Monday.)

REFINERY GASOLINE

Octane (A.S.T.M.)	78-80†	73-75
Mid-Continent*	5.625-6.00	5.00-5.25
Texas Gulf Coast	6.375	5.375-5.75
New York Area		7.425-7.90
California		6.00-6.875

*Basic Oklahoma Group 3. †1939 C.F.R. (research method).

NATURAL GASOLINE

Grades:	26-70	18-55
Oklahoma (Group 3)	2.750	3.300
N. Texas (f.o.b. plant)	2.250	2.700
N. Louisiana (f.o.b. plant)	2.625	3.150
California	4.875	5.500

CRUDE-OIL PRICES

Representative posted schedules per bbl.

East Texas	$1.25
Conroe	1.43
Tepetate, Louisiana, avg. grav.	1.20
Illinois Basin	1.37
Pecos County, Texas	.95
Bradford, Pennsylvania	3.00
Van, Van Zandt County, Texas	1.08

Note: Exclusive of subsidy.

GRAVITY SCHEDULES

Top prices include all gravities above grades designated, and low prices include all gravities below grades designated:

Gravity—	Signal Hill, Calif.	Oklahoma, Kansas	Gulf Coast Texas	West Tex.*
18-18.9	$0.80			
19-19.9	.84		$1.06	$0.70
20-20.9	.88	$0.85	1.08	.72
21-21.9	.92	.87	1.10	.74
22-22.9	.96	.89	1.12	.76
23-23.9	1.00	.91	1.14	.78
24-24.9	1.03	.93	1.16	.80
25-25.9	1.07	.95	1.18	.82
26-26.9	1.11	.97	1.20	.84
27-27.9	1.15	.99	1.22	.86
28-28.9	1.18	1.01	1.24	.88
29-29.9	1.20	1.03	1.26	.90
30-30.9	1.23	1.05	1.28	.92
31-31.9		1.07	1.30	.94
32-32.9		1.09	1.32	.96
33-33.9		1.11	1.34	.98
34-34.9		1.13	1.36	1.00
35-35.9		1.15	1.38	1.02
36-36.9		1.17	1.40	1.04
37-37.9		1.19	1.42	1.06
38-38.9		1.21	1.44	1.08
39-39.9		1.23	1.46	1.10
40 and above		1.25	1.48	1.12

*Includes Lea County, New Mexico.

A.P.I. REFINERY REPORT

Week ended March 16, 1946

(Figures in thousands of barrels)

	Dly. crude runs to stills	Stocks—Gasoline	Distillate	Residual
East Coast	763	23,305	7,926	6,093
Appalachian	151	4,056	477	539
Ill., Ind., Ky.	751	24,213	3,100	3,043
Okla., Kan., Mo.	392	9,892	1,438	959
Inland Texas	203	3,091	300	629
Tex. Gulf Cst.	1,091	15,669	4,262	4,062
La. Gulf Coast	301	4,427	1,189	1,179
N. La., Ark.	58	1,891	451	245
Rocky Mt.	136	2,491	415	596
California	761	15,746	6,189	20,422
Total 3-16-46	4,607	104,781	25,747	37,767
Total 3- 9-46	4,656	104,901	25,131	38,388
Total 3-17-45	4,751	98,405	25,874	43,243

CRUDE-OIL STOCKS

(Bureau of Mines Estimate)

Week ended:	Bbl. of crude*
March 16, 1946	226,233,000
March 9, 1946	226,112,000
March 17, 1945	219,486,000

*Excludes unrefinable Calif. stocks.

TRENDS

DAILY AVERAGE PRODUCTION FOR WEEK

	Mar. 23 crude oil	Bureau of Mines March demand	Mar. 16 crude oil
Alabama	1,000	500	1,000
Arkansas	77,250	76,000	77,050
California	859,750	838,000	847,750
Colorado	22,200	23,000	22,340
Eastern	65,100	61,200	63,900
Florida	100	100	100
Illinois	208,600	198,000	206,300
Indiana	17,600	13,000	17,850
Kansas	259,350	252,000	252,750
Kentucky	32,050	29,000	32,100
Louisiana	375,800	372,000	375,900
North Louisiana	82,450	.....	82,550
South Louisiana	293,350	.....	293,350
Michigan	44,270	46,000	43,250
Mississippi	55,250	52,000	55,100
Montana	23,710	20,400	23,440
Nebraska	800	800	800
New Mexico	95,150	98,000	95,150
Oklahoma	367,500	366,000	371,500
Texas	1,817,450	1,910,000	1,817,450
East Texas	317,400	.....	317,400
East Central Texas	127,500	.....	127,500
North Central Texas	146,050	.....	146,050
Texas Panhandle	81,000	.....	81,000
West Texas	436,500	.....	436,500
Southwest Texas	290,200	.....	290,200
Texas Gulf Coast	418,800	.....	418,800
Wyoming	100,270	94,000	100,600
Total United States	4,423,200	4,450,000	4,404,330
Change from previous week	up 18,870		

Total production January 1-March 23 ..... 383,930,470 bbl.
Same period last year ..... 389,018,150 bbl.

CRUDE-OIL STOCKS 226,233,000 bbl. as of March 16—up 121,000 bbl. One year ago 219,486,000 bbl.

GASOLINE STOCKS 104,781,000 bbl. as of March 16—down 120,000 bbl. One year ago 98,405,000 bbl.

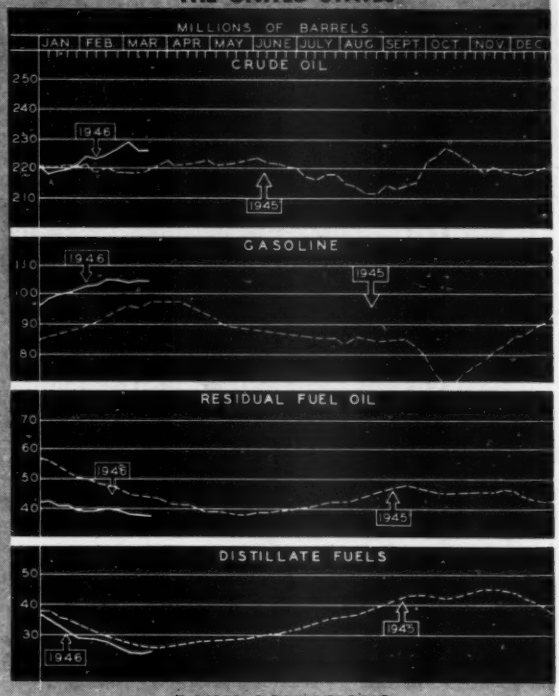
RESIDUAL FUEL-OIL STOCKS 37,767,000 bbl. as of March 16—down 621,000 bbl. One year ago 43,243,000 bbl.

GAS OIL AND DISTILLATE STOCKS 25,747,000 bbl. as of March 16—up 616,000 bbl. One year ago 25,874,000 bbl.

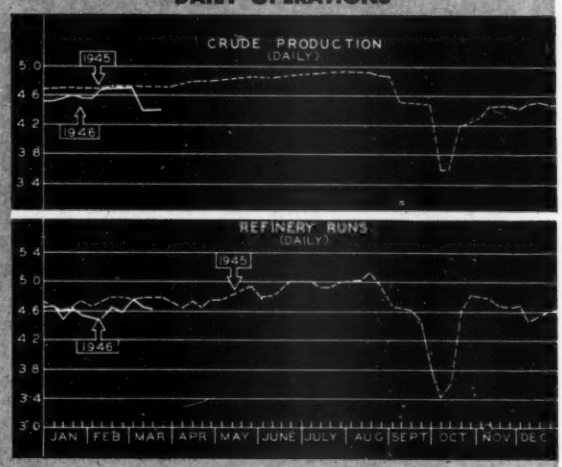
CRUDE-OIL PRODUCTION 4,423,200 bbl. as of March 23—up 18,870 bbl. One year ago 4,782,300 bbl.

REFINERY RUNS 4,607,000 bbl. daily week ended March 16—down 49,000 bbl. One year ago 4,751,000 bbl.

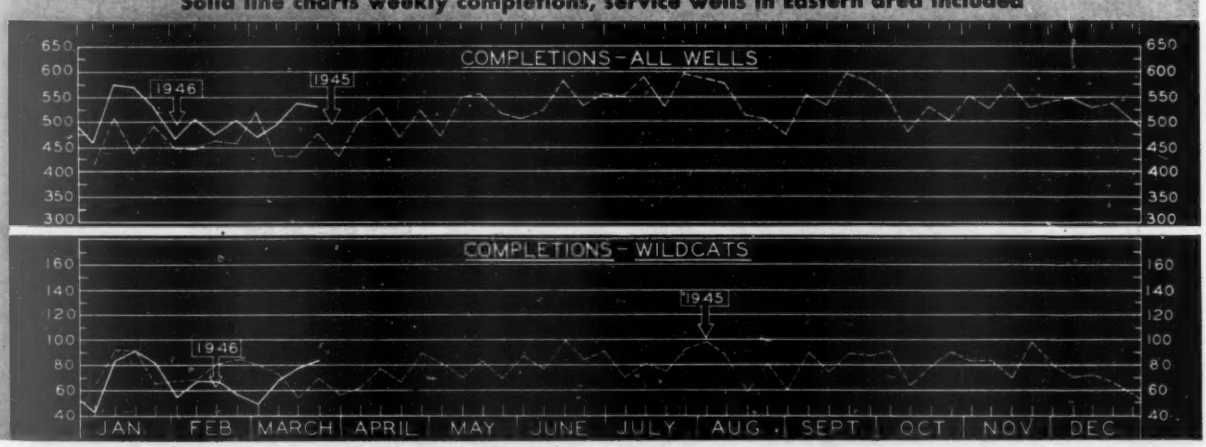
OIL STOCKS IN THE UNITED STATES



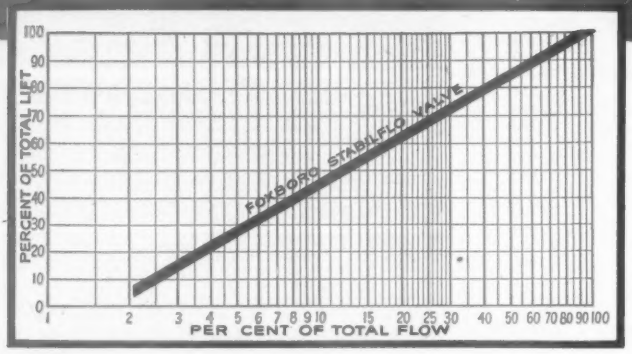
DAILY OPERATIONS



Solid line charts weekly completions, service wells in Eastern area included



Only Stabilflo Valves will give you this remarkable performance



50 to 1 RANGEABILITY WITH UNIFORM CHARACTERISTICS

With this unique valve, you now can be sure that the extraordinary sensitivity, accuracy, and dependability of precision-engineered controllers are translated into matching valve performance.

The unique characteristics of the Foxboro Stabilflo Control Valve are graphically revealed in the chart above; . . . *equal increments in controller output (and valve lift) produce equal percentage changes in flow.* Thus under constant pressure drop conditions and on a semi-logarithmic scale, the line plotted is straight.

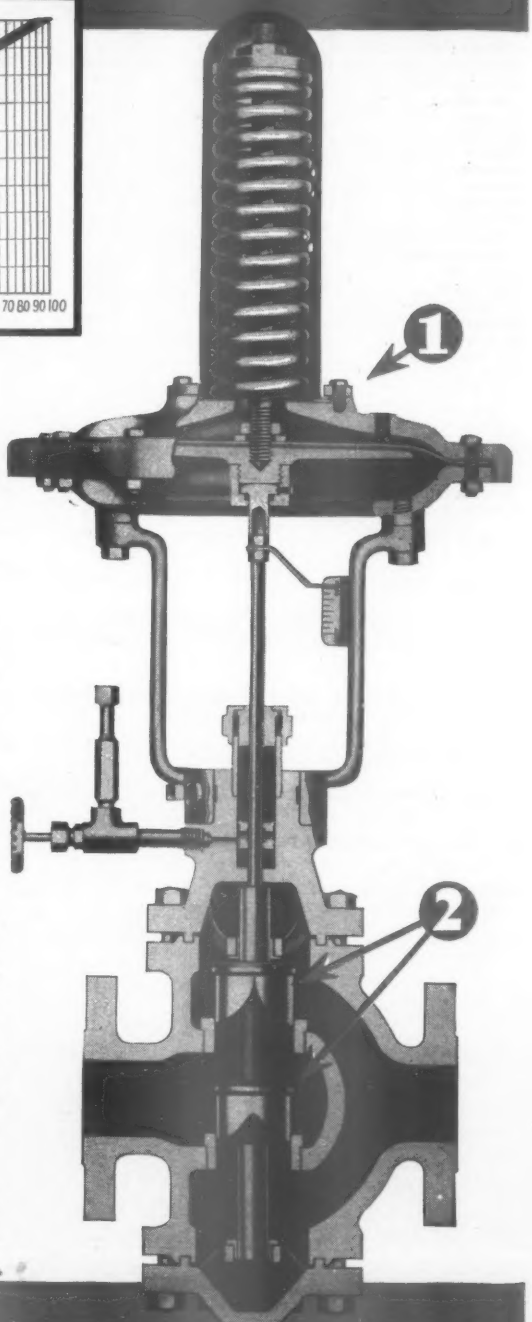
This achievement was made possible by two major Foxboro developments in valve design. . . .

1 THE INVERTED TYPE MOTOR . . . By reversing the usual position of diaphragm and spring, Foxboro engineers practically eliminate all sources of friction in the action of the motor. Anti-friction bearings are unnecessary. The suspended construction of the valve motor requires no guides. A special flexible coupling between the valve stem and the diaphragm motor allows the stem to establish normal alignment.

This self-aligning motor with its floating action is an exclusive feature of Foxboro Stabilflo Valves.

2 WIDE RANGE V-PORT VALVES . . . This outstanding development corrects the common faults of control valves of conventional types. Almost any kind of port opening can produce equal percentage flow changes within a limited range, but Foxboro's WIDE RANGE V-PORT VALVE extends the limits to the full stroke of the motor. The greater the rangeability possessed by a valve, the greater its ability to handle unusual conditions. Hence, the 50 to 1 rangeability means that the Stabilflo Valve insures satisfactory control at all demands.

Since the success of any control system may depend as much on the performance of the valve as on the control instrument, it will pay you to investigate the advantages of Stabilflo Valves. Write for complete information. **The Foxboro Company, 60 Neponset Ave., Foxboro, Mass., U. S. A.** Branches in principal cities.



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AUTOMATIC CONTROL VALVES

Exploration and Drilling

Wyoming Tests in Limelight

THROUGHOUT the Rocky Mountain area, the northern Mid-Continent, and on the West Coast, geologists and executives are paying close attention this week to news from Pure Oil Co.'s two tests on the River Dome structure in Washakie County, Wyoming, north of Worland, because of their important bearing on the whole question of exploration in the inner basins in the Rocky Mountains. (For previous references to this play, see The Oil and Gas Journal, March 10 and 17, and October 6, 1945.

Pure's first well, 1 Unit, NE NE NW 18-48n-92w, has been drilled to a total depth of around 11,000 ft., deliberately designed to test as much of the sedimentary section as possible, regardless of any promising shallow pays. The second well, 2 Unit, is located north and a little west of the first, in NE corner Lot 1, 12-48n-92½w, a small correction range.

The first well, after finding nothing worth while in the Tensleep, and probably in the Amsden, has backed up and in testing the Embar lime (Permian), found what looks like a good well. Top of the Embar is reported at 9,978 ft., and a drill-stem test at 9,990 to 10,020 ft. showed an estimated 5,000,000 cu. ft. of sour gas. This was followed by a second test, after perforating the interval 10,020-55 ft., with 140 shots. The second test, taking in the whole interval 9,990 to 10,055 ft., showed gas and a substantial quantity of 41.5° oil. Tubing has been run for a production test, possibly to be followed by an acidizing job and another production test.

This first well has previously had cores and drill-stem test results in the Frontier sands, indicating strong probabilities that a good gas-condensate well could be completed around 7,229-72 ft. Another drill-stem test in the Muddy sand, somewhere around 8,150 ft., is reported to have looked good for 200 bbl. daily of condensate.

While the first well was getting these results in the Embar, the second well, started to test the shows previously obtained in the Frontier, is reported to have made a drill-stem test at 7,534-54 ft., and obtained a gas flow in 45 seconds, condensate in 16 minutes, with estimates that it would produce 300 bbl. daily. It was deepened and a drill-stem test at 7,557-88 ft. recovered only dry gas in small volume. It is now drilling ahead, below 7,670 ft., possibly for the purpose of testing the Muddy sand.

With reported respective elevations of 4,034 ft. and 4,117 ft., on the first and second wells, the following points are believed to be reasonably accurate. First well: First Frontier sand top —3,099 ft., second Frontier top —3,208 ft., Muddy sand somewhere around —4,100 ft., Embar —5,944 ft., Tensleep —6,207 ft. Second well: First Frontier sand —3,311 ft., second Frontier —3,413 ft. These points indicate the second well is running something over 200 ft. lower than the first.

If the reports on the gravity of the Embar oil in the deep well are correct, this will have an important bearing on the future of very deep testing in the Wyoming basins. Hitherto the Paleozoic formations in this part of Wyoming have always carried low gravity, black oil with a high sulfur content and a price of usually less than $1. With the high cost of deep drilling, even very high acre yields did not offer too attractive a return for the risk, while average yields just didn't justify drilling.

One of the attractions of the inner-basin wildcat campaign was the possibility of getting light Cretaceous oil, with a price tag that offered profit possibilities if something were found. The results to date in the Frontier sands and in the Muddy sand indicate this will probably work out.

Now if the deeper Paleozoic horizons are to carry high gravity oil, even though it is sour crude, the inner basin testing will become doubly attractive.

SOUTH LOUISIANA

Jefferson Parish Discovery Flows 300 Bbl. Daily

NEW ORLEANS.—A new oil field, approximately 5 miles east of the Barataria field in Jefferson Parish, has been opened by The California Co. at 1 E. P. Brady et al, on State Lease 4, 66-13s-24e. Drilled to a total depth of 10,680 ft., the discovery came in through the drill stem, and after tubing was run, it gaged 300 bbl. of 38°-gravity oil daily, showing a 0.1 per cent basic sediment cut, with 1,400 lb. flowing pressure on the tubing, through a 9/64-in. choke. Gas-oil ratio 343 to 1. Completion is from the 9,300-ft. level. A new location for the area has been staked by California, which is 2 E. P. Brady et al, 24-15s-24e, approximately 1 mile southeast of the discovery, just over the parish line in Plaquemines Parish.

Atlantic Refining Co. has started the first of their three wildcat tests in Lake Ponchartrain which are all scheduled to seek sands down to the 12,000-ft. level. The current test is 1-C State, in the Metairie area of Jefferson Parish on State Lease 318, Unit 3, Block 8, and is drilling below 1,829 ft.

The 12 new locations this week are all in proven areas with Acadia, Jefferson, and St. Mary parishes receiving 2 each. The total proposed footage to be drilled is 110,450 ft. Only three completions were reported this week, one oil well in St. Martin Parish, Anse La Butte field, one dry hole in Hope Villa field, East Baton Rouge Parish, and one dry wildcat in St. Mary Parish.

SOUTH LOUISIANA WILDCAT FAILURE

St. Mary Parish: Humble Oil & Ref. Co. 1 J. M. Burguieres Co., Ltd., et al, 22-15s-7e, in Cote Blanche Island area, dry, TD 7,809 ft.

TEXAS GULF COAST

Gas-Condensate Pool Found In San Jacinto County

HOUSTON.—A new gas-condensate pool has been opened in San Jacinto County, southwest of the Mercy field, 7 miles southwest of the townsite of Shepherd, by Fred M. Manning, Inc. 1 Central Coke & Coal Co., in the James Ferguson Survey, Abstract 119. Drilled to a total depth of 11,001 ft., the discovery is producing 14 bbl. of 50°-gravity condensate daily, with estimated 285,000 cu. ft. of gas, through a 13/64-in. choke. Tubing pressure 260 lb., with 725 lb. pressure on casing. Gas-oil ratio 19,370 to 1. Production is from the Wilcox through 344 perforations at 8,310-45 ft. The 4½-in. drill pipe stuck at 10,714 ft. and operators cemented it at that depth and perforated for completion.

New oil sand for the South Liberty field, in Liberty County, has been opened by F. J. Bashara 2 H. L. McGuire. Located in M. G. White Survey, this well was drilled to a total depth of 3,796 ft., with top of sand 3,299 ft. On potential test it flowed 198 bbl. per day through ⅛-in. choke, tubing pressure 280 lb., gravity 22°, with 1.4 per cent water. Production is through perforations at 3,299-3,309 ft.

Humble Oil & Refining Co. 16-Y Luther R. Sherrod, deep test in the Raccoon Bend field of Austin County, in the Wm. C. White Survey, attempted to blow out while drilling at a depth of 11,018 ft. and operators are increasing weight of the mud. A string of 9⅝-in. protection casing was cemented to 8,843 ft. Last test was made from 8,786-8,801 ft. where 60 ft. of drilling mud showing a cut of oil and gas was recovered.

Twenty-three new locations reported this week included four wildcats, one each in Chambers, Jefferson, Montgomery, and

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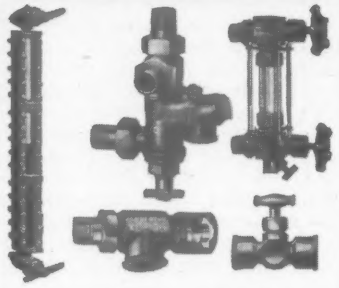

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Tyler counties. Brazoria, Wharton and Liberty counties received three new locations each. All three locations in Liberty County are in Kirby field. Five of the locations are scheduled to be drilled deeper than 10,000 ft. Two new pools were opened this week, a gas-condensate discovery in San Jacinto County, and an oil pool in Chambers County. One new oil sand was opened in Liberty County. Two dry wildcats, one each in Harris and Jefferson counties, and 12 field wells were completed this week.

UPPER GULF COAST TEXAS SUCCESSFUL WILDCATS

Chambers County: New oil pool—South Mayes field—Humble 1 Lulu Wallis et al, Samuel Mather Sur., Abst. 192, Blk. 13, Tract 1, TD 10,010 ft., top sand 9,194 ft., perf. 24 holes 9,194-98 ft., PT 185 bbl. 24 hours through 3/64-in. choke, gas-oil ratio 10,530 to 1, TP 3,175 lb., gravity 36°, 0.2 per cent water.

Liberty County: New oil sand South Liberty field—F. J. Bashara 2 H. L. McGuire, M. G. White Survey, TD 3,796 ft., top sand 3,299 ft., perf. 3,299-3,309 ft., PT 198 bbl. 24 hours through a ½-in. choke, TP 280 lb., gravity 22°, 1.4 per cent water.

San Jacinto County: New gas-condensate pool—Fred M. Manning, Inc., 1 Central Coke & Coal Co., J. Ferguson Sur., Abst. 119, 2½ mi. SW of Mercy field, TD 11,001 ft., PB 8,351 ft., top sand 8,310 ft. (Wilcox), perf. 344 holes from 8,310-45 ft., PT 14 bbl. 24 hours through 13/64-in. choke and 285,000 cu. ft. gas per day, gas-oil ratio 19,370 to 1, TP 260 lb., CP 725 lb., gravity 50°, no water.

UPPER GULF COAST TEXAS WILDCAT FAILURES

Harris County: William Helis 1 Foster Lbr. Co., Amasa Turner Survey, dry, TD 8,661 ft.

Jefferson County: McCarthy Oil & Gas Corp. 1 Geo. Gill Estate et al, T&NO Sur., Section 141, dry, TD 9,265 ft.

EASTERN TEXAS

Shelby Wildcat Shows Gas and Distillate

DALLAS.—Humble Oil & Refining Co. 1 Pickering, Francois Survey, wildcat in the Huxley area of eastern Shelby County, flowed gas and distillate into pits after reperforating from 6,606-28 ft. The well had flowed 18 bbl. of 57°-gravity distillate and 1,836,000 cu. ft. of gas on a previous gage. Barnsdall Oil Co. and Sohio Petroleum Co. 1 Pickering, R. E. Sevey Survey, Smackover discovery 2½ miles southwest of Texarkana, Bowie County, gaged 81.2 bbl. distillate and 4,200,000 cu. ft. of gas in 24 hours through 20/64-in. tubing choke. Gas-distillate ratio is 51,800 to 1. This gage shows an increase in production.

Tex-Harvey Oil Co. 1 Reitch, O. Weir Survey, is a new discovery for Cherokee County 10 miles northeast of Rusk. The well flowed 7.95 bbl. of distillate and 14 bbl. of salt water through a ⅛-in. choke. It was producing through casing perforations from 4,351-52 ft. in the Woodbine. Gas was estimated at 750,000 cu. ft. daily with tubing pressure of 1,360 lb. and casing pressure of 1,560 lb.

Chicago Corp., formerly Delta Drilling Co., 1 Rayford, Smith Survey, discovery 3 miles south of Henderson, Rusk County, gaged 19.88 bbl. of oil and distillate and 1.95 bbl. of salt water with 1,060,000 cu. ft. of gas in 24 hours through ⅛-in. tubing choke. Gravity was 60°. Gas-oil ratio was 53,000 to 1.

Hawkins field, Wood County, had eight completions this week and Carthage field, Panola County, had three. Hawkins and Merigale fields, Wood County, each had three locations and Talco field, Franklin County, Waskom field, Harrison County, and Carthage field each had one. Carthage field has 23 drilling wells; Hawkins field, 20; New Hope field, Franklin County, 7, and Sand Flat field, Smith County, 6.

EASTERN TEXAS SUCCESSFUL WILDCAT

Cherokee County: New oil pool—Tom G. Shaw, Tr., 1 John H. Bolton, Chas. L. Widgeon Sur. A-938, 3½ mi. SW Summerfield, elev. 277 ft., pumped 6 bbl. day, perf. 4,171-74 ft. Woodbine, gravity 41°, TD 4,177 ft.

EASTERN TEXAS WILDCAT FAILURES

Panola County: Ohio 1 J. O. Britton, Wm. Taylor Sur., 1¼ mi. NE Dotson, elev. 358 ft., Pettit 6,280 ft., Travis Peak 6,670 ft., dry, TD 7,001 ft.

Smith County: Chapel Hill Gas System et al 1 Chas. Mayfield, Jesse Dunlap Sur., 2½ mi. S and slightly E Starville, elev. 476 ft., massive anhydrite 7,347 ft., Lower Glen Rose 7,592 ft., dry, TD 8,529 ft.

Wood County: Delta Drlg. 1 J. B. White, J. Stark Sur., 5½ mi. NE Quitman, elev. 446 ft., Woodbine 5,010 ft., dry, TD 5,506 ft.

PERMIAN BASIN

First Oil Production for Kent County Indicated

MIDLAND.—Possibilities of first oil production for Kent County was indicated at Humble Oil & Refining Co. 1 Lida Vick, Section 45, Block 5, H&GN Survey, 2 miles northwest of Polar in the southern part of the county. Ellenburger was topped at 7,773 ft., with elevation of 2,332 ft. On a 1-hour drill-stem test from 7,780 to 7,812 ft. recovery was 2,396 ft., of which the top 50 ft. was drilling fluid and the remainder clean oil. The well headed some oil when drill pipe was being pulled. Estimated fill-up was at the rate of 30 bbl. of oil per hour. During the test there was gas to the surface in 11 minutes with the well making 84,000 cu. ft. at the end of 21 minutes. Flowing pressure was 875 lb. The well is being drilled deeper.

Atlantic Refining Co. 1-A University, Section 1, Block 11, University Land Survey, deep test in the West Andrews pool of southern Andrews County and 1½ miles southeast of Ellenburger production in the Martin pool, was preparing to take drill-stem test on the Ellenburger. The well, which showed for production in the McKee section of the Simpson, also productive in the Martin pool, was drilled to 8,825 ft. in the Ellenburger, topped at 8,670 ft. It is 141 ft. higher structurally than the Ellenburger production in Martin pool. Humble 2 J. E. Parker, Section 23, Block A-41, Public School Land Survey, ⅜ mile southeast of Sun Oil Co. 1 Martin, opener of the Martin pool and producing from the Clear Fork, has opened Ellenburger production in the Martin pool, flowing 1,594 bbl. of 42.3° gravity oil on official test. Production was through perforations from 8,850-65 ft. Ellenburger was topped at 8,836 ft., 5,526 ft. below sea level.

Stanolind Oil & Gas Co. 1 Mike Veretto, Labor 7, League 72, Val Verde County School Land Survey, San Andres lime discovery in Hockley County 2¾ miles southeast of the Levelland field, has been completed for a 24-hour flow of 342.72 bbl. of oil plus 29.81 bbl. of water. Gas-oil ratio was 1,901 to 1. The well cemented 7-in. casing at 4,690 ft., topped the pay at 4,750 ft., drilled to 4,889 ft. and plugged back to 4,853 ft. It was treated with 10,500 gal. of acid in two stages.

Argo Oil Corp. 1 Dora Roberts, Section 29, Block 13, H&GN Survey, wildcat in Reeves County, 13 miles northeast of Balmorrhea, had a slight showing of gas in drilling to 9,962 ft. in lime. A 1-hour drill-stem test was run from 9,934-62 ft., using

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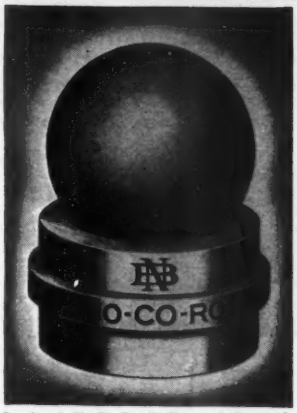

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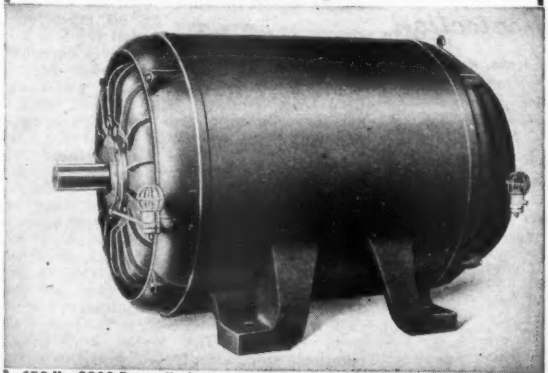

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2,040-ft. water blanket. Recoverey was water blanket and 10 ft. of mud with no shows.

Garza field, Garza County, reported 11 completions this week; Slaughter field, Hockley County, 4; McElroy field, Crane County, Keystone-Ellenburger field, Winkler County, Welch field, Dawson County, 3 each, and Block 31 pool, Crane County, 2. Welch field had 12 locations, TXL field, Ector County, and Keystone-Holt field, Winkler County, each 3, and Foster field, Ector County, Todd Deep, Crockett County, and Keystone-Ellenburger field each 2. TXL field has 38 drilling wells; Keystone-Ellenburger 34; Fullerton field, Andrews County, 26; Block 31 field, Crane County, 21, and Welch field, Dawson County, 13.

SOUTHEASTERN NEW MEXICO

HOBBS.—Tide Water Associated Oil Co. staked a northeast outpost to the Brunson (Ellenburger) field southeast of Eunice in western Lea County following completion by Magnolia Petroleum Co. 10 Argo-Brunson for a 14-hour flow of 253 bbl. of oil. Tide Water 2 E. A. Sticker will be 660 ft. from the south line and 810 ft. from the east line of 4-22s-37e. Magnolia 10 Argo-Brunson, 9-28s-37e, extended production ¼ mile east. It produced 40.4° gravity oil from 7,880-95 ft. Gas-oil ratio was 865 to 1. Lion Oil Co. 1 Wylie, 5-23s-38e, ½ mile east of production on the southeast side of the Drinkard field, Lea County, logged a soft streak from 8,184-87 ft. in the Waddell section of the Simpson. Core from 8,187-8,192 ft. recovered 3½ ft. of fine hard sand with no shows. It was drilling ahead. Culbertson & Irwin, Inc., 1-D State, 9-28s-37e, wildcat in south central Lea County, 3 miles northwest of the West Eunice field, was dry at 4,005 ft. in lime with no shows.

Grayburg-Jackson, Russell, Lusk and Loco Hills fields, Eddy County, each had one completion this week. Empire field, Eddy County, Brunson, Paddock and Eaves fields, Lea County, each had one location. Drinkard field, Lea County, and Grayburg-Jackson field, Eddy County, each have seven drilling wells; Paddock field, Lea County, six, and Penrose-Skelly field, Lea County, five.

SOUTHEASTERN NEW MEXICO SUCCESSFUL WILDCAT

Lea County: Extension to old oil pool—Gulf 1 Hugh, 14-22s-37e, Drinkard field, flowed 62 bbl. day, perf. 5,120-60 ft. Glorietta, gravity 40°, TD 6,463 ft.

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SOUTHWEST TEXAS

New Deep Sand Opened South of Yoakum Field

CORPUS CHRISTI.—Pure Oil Co. 1 E. F. Karl opened a new, deeper pay sand about ½ mile south of the Yoakum field gas-condensate discovery in DeWitt County. After drilling to a total depth of 11,334 ft., operators plugged back to 8,690 ft., squeeze job was made at 8,672-74 ft., and well is flowing 130 bbl. of 34°-gravity oil per day through perforations at 8,663-65 ft. This is the first oil production for this field, and is located approximately 3 miles southeast of Yoakum townsite, in the John May Survey, Abstract 329. The discovery well, Pure 1 Eugene Rice, was completed through perforations at 8,160-90 ft. for a 52°-gravity condensate well, with total depth of 9,185 ft. and 5½-in. casing set to 8,729 ft.

A northeast extension to the Calvert field, Milam County, is flowing 35 bbl. of oil by heads in 8 hours from Nacatosh sand topped at 2,104 ft. The well, McCrary Oil Co. 1 J. R. and M. A. McCrary, was drilled to a total depth of 2,120 ft. in sand, 5½-in. casing set at 2,095 ft. This is the second oil production on the Milam County side of the Brazos River, and is north of the main Calvert field production in Robertson County.

Second test in the North Minnie Bock area of Nueces County, Atlantic Refining Co. 2 Jas. H. Ewing, Section 46, Geo. H. Pauls subdivision of Driscoll Ranch, is flowing into pits, making oil and wash water through perforations at 6,229-35 ft. with 40 shots in a new pay zone. It is cleaning on a 5/32-in. choke with 480 lb. tubing pressure. If it makes an oil producer, it will be the oil discovery well for this area. The 1 Ewing discovery well was completed in January for a gasser through perforations 8,254-68 ft. The 2 Ewing was drilled to a total depth of 8,495 ft. and set 7-in. casing to bottom. This area lies approximately 3 miles southwest of Robstown and 1½ miles north of the Minnie Bock field.

There were 27 new locations reported this week with 6 being wildcats, 1 each in Bee, Duval, Jim Hogg, Milam, Uvalde, and Webb counties. Duval and Nueces counties received the greatest activity with four new locations each. A new gas-condensate pool was opened in Atascosa County, and Milam County received a new oil pool. There were seven dry wildcats reported, two in Live Oak, one each in Bastrop, Caldwell, Edwards, Jim Wells, and LaSalle counties. Starr County led with three completions reported.

SOUTHWEST TEXAS SUCCESSFUL WILDCATS

Atascosa County: New gas-condensate pool Quintana Petroleum Corp. 1 C. Muil, in J. C. Mattison Survey 467, 11 mi. SE of Pleasanton, 4 mi. NE of McCoy and 9 mi. N of Campbellton, originally abandoned at old TD 8,865 ft., plugged back and sidetracked and drilled to new total depth of 9,012 ft., top sand 9,000 ft., Edwards lime, acidized open hole 8,870-9,012 ft., PT estimated 3,000,000

cu. ft. gas and 50 bbl. condensate per day, through ¼-in. choke, gas-oil ratio 60,000 to 1, TP 2,450 lb., shut-in pressure 3,250 lb., gravity 50°, no water.

Milam County: New oil pool, Holcomb field—R. L. Holcomb et al 2 J. L. Byrd, J. J. Acosta Grant, 1 mi. NE of Sharp, top sand 1,210 ft. Austin chalk, TD 1,384 ft., no perforations, 5½-in. casing at 1,220 ft., 2-in. tubing at 1,240 ft., PT 55 bbl. oil per day on pump, no gas, gravity 34°, no water.

SOUTHWEST TEXAS WILDCAT FAILURES

Bastrop County: C. W. Voyles 1 A. E. Rosanky, Musgrove Evans Sur., 12 mi. S of Bastrop, dry in Navarro sand, TD 2,814 ft.

Caldwell County: Clyde Lane 1 A. W. Jolley, J. B. Gray Survey, dry, Edwards lime, TD 1,378 ft.

Edwards County: Meco Prod. Co. et al 1 J. W. Holman, CCSD&RGNG Sur. 25, dry, TD 1,053 ft.

Jim Wells County: Shell Oil Co., Inc. 1 William Van Hoogenhuyze, De La Garza Grant, 2 mi. E of Wilson field, dry, TD 10,086 ft.

LaSalle County: Humble Oil 1 St. Louis Union Trust & Co., GB&CNG Sur., dry, TD 7,200 ft.

Live Oak County: Sid Katz and Texon Oil Co. 2 Bronson, L. Jacobs Sur. 2, dry, TD 1,412 ft.

Live Oak County: Producers Corp. of Nevada 1 B. V. Mathieson, W. Freeman Sur. 272, dry, TD 4,476 ft.

Milam County: Andre & Foster 1 E. Dornhoefer, S. C. Robertson Sur., 3 mi. W of Rockdale, dry, TD 710 ft.

APPALACHIAN FIELD

Large Gas Wells Feature Eastern Completions

PITTSBURGH.—In Big Sandy district, Kanawha County, West Virginia, Falling Rock Producing Co. completed its Oriskany test on its fee with a final open flow of 7,055,000 cu. ft. gas, natural, with a rock pressure of 1,700 lb. in 8 hours. It is located about 3 miles slightly north of east of the discovery well in the new extension to the Elk-Poca field and about 1 mile slightly east of north of the good well on the Fred Thabet farm. The new area now extends about 6 miles east and west by 1½ miles north and south.

In Ravenswood district, Jackson County, United Carbon Co. completed the test 1,336 J. F. Folden and it gaged 3,180,000 cu. ft. gas, natural, from the Oriskany sand.

In Baileysville district, Wyoming County, United Producing Co. completed another good Berea gas well in 1,316 W. M. Ritter Lumber Co., which gaged 3,162,000 cu. ft. gas, after shot. The Berea sand was placed at 3,245 ft., total depth 3,284 ft.

New locations in West Virginia totaled 38 scattered in Barbour, Braxton, Cabell, Calhoun, Doddridge, Jackson, Kanawha, Lewis, Lincoln, Logan, Mingo, Raleigh, Ritchie, Upshur, Wayne, Wirt, Wood, and Wyoming counties.

In South Beaver Township, Beaver County, southwest Pennsylvania, Beaver Hill Oil & Gas Co. topped the Onondaga lime at 4,742 ft. in the Oriskany test on C. C. Kennedy farm and is shut down with a fishing job. The Berea was placed at 948-965 ft.

In Greene Township, Erie County, the Oriskany wildcat of Appalachian Development Corp. on Alfred Halm farm topped the Tully lime at 2,050 ft., the Onondaga lime at 2,290 ft., and shut down at 2,396 ft. The surface elevation is 1,317 ft.

New locations in Pennsylvania totaled 12 and were situated in Bethel, Boggs, Buffalo and Wayne Townships, Armstrong County; Limestone Township, Clarion County; German and Nicholson townships, Fayette County, and Monongahela and Washington townships, Greene County.

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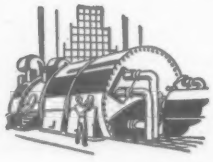

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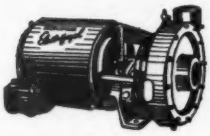

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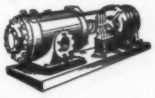

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CANADIAN FIELDS

Large Producer Indicated In Turner Valley Offset

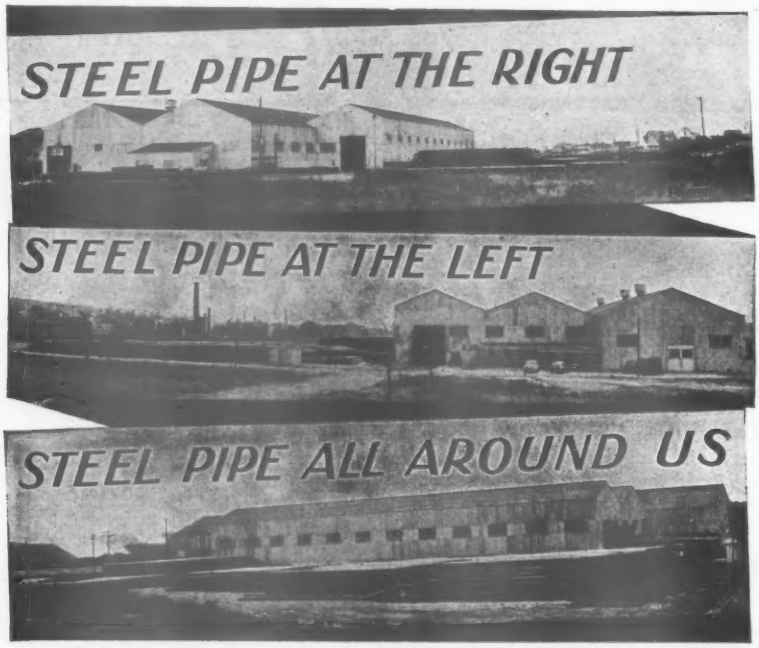
CHATHAM.—In Turner Valley North Extension, Continental Oil 1, LSD 8, 4-21-3w5, is drilling lower porous after contacting the Madison lime at 7,918 ft. This well, first of a series of offset tests, had 301 ft. of porosity in the upper lime, and a large producer is indicated.

Jumping Pound.—On the Jumping Pound structure in the Alberta foothills west of Calgary, Shell 16-14-J, LSD 16, 14-25-5w5, is in upper Benton below 5,300 ft. after 2 months' drilling. Location is immediately southwest of Shell 4-24-J, LSD 4, 24-25-5w5, which in December 1944 finished at 9,947 ft., after encountering wet gas and light crude in the Madison. Two subsequent tests proved off structure, encountering salt water in the lime at greater depth.

Brazeau.—In the Central foothills, Home-Brazeau 1, LSD 5, 17-43-17w5, which discontinued drilling at 11,689 ft. after faulting from the second Madison sequence to upper Blairmore, got 50,000 cu. ft. gas in drill-stem test of the lower lime. Liner has been cut below the upper lime and cement plug set for a retest of the upper lime which showed around 1,000,000 cu. ft., and this formation may be acidized.

Keho Lake.—The Keho Lake area of southern Alberta will be tested by Okalta Oils of Calgary which has secured 10,158 acres in 11-22w4, extending within ½ mile of Keho Dome 1, LSD 3, 18-11-22w4, now standing at 3,880 ft. Okalta acreage includes the location of Hudson's Bay-Marland 1, LSD 2, 17-11-22w4, abandoned in 1934 owing to drilling and production difficulties after encountering oil in two horizons of the Colorado and one in Lower Cretaceous. Production of 29.4-gravity oil was taken for some time from the Colorado. Drilling outfit has been secured and the company plans to carry on a simultaneous 5-rig program if No. 1 gets production.

Alberta production.—Crude oil production in Alberta in 1945, representing 94.01 per cent of Canada's total, reached 8,055,440 bbl., a decline of 733,286 bbl. from 1944. Turner Valley production decreased 904,-253 bbl. and that from Alberta fields outside Turner Valley gained 170,967 bbl. The footage drilled for the year totaled 543,437, with 159,049 for Turner Valley and 384,388 outside.



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ROCKY MOUNTAIN

River Dome Prospect To Test Embar

DENVER.—Pure Oil Co. 1 Unit, NE NE NW 18-48n-92w, River Dome district, Washakie County, Wyoming, stopped drilling at 11,379 ft., and is preparing to plug back and test the Embar. It had the top of the Tensleep at 10,245 ft., showing some saturation at 10,280-10,305 ft. Top of the Amsden was at 10,420 ft., and of the Madison at 10,570 ft., drilling stopping in the Big Horn. A drill-stem test at 10,235-11,379 ft., open 1½ hours, resulted in 3,420 ft. of mud and 5,400 ft. of brackish mud. A show for 200 bbl. per day of condensate and 5,000,000 cu. ft. of gas per day was encountered in the Muddy, topped at 8,117 ft. The Frontier was cased off with the 9⅝-in. at 7,596 ft. A second well drilling to the north which will test these upper horizons is now below 7,462 ft.

Rattlesnake Butte test.—H. H. Swartz, Jr. Government, C SW SE 22-13n-28e, Rattlesnake Butte structure, 15 miles south of the Cat Creek field, Montana, which swabbed 4 to 5 bbl. an hour from the second Cat Creek sand at 2,780-2,810 ft., and indicated a discovery, has been standing without further testing due to road conditions which has delayed moving in a spudder to condition the hole and make a test. A short string of 2-in. tubing was stuck in the top of the casing and through this there has continued a small trickle of oil over the top amounting to 4 or 5 bbl. per day.

Gas at Table Rock.—The Texas Co. 1 Unit, SE NW NW 1-18n-98w, Table Rock structure, a test near the center of Sweetwater County, Wyoming, 50 miles north of the Powder Wash field and 60 miles southwest of Lost Soldier, has reached an interesting stage. Total depth is 3,417 ft. Down to this depth 26 drill-stem tests have been made. One at 3,325-35 ft., open 50 minutes, recovered 1,790,000 cu. ft. of dry gas, no water. Another at 3,332-45 ft., open 45 minutes, recovered 2,440,000 cu. ft. of dry gas, no water. Next one at 3,345-65 ft., open 35 minutes, recovered 1,900,000 cu. ft. with 150 ft. of water. Last one taken at 3,355-65 ft., open 30 minutes, recovered 124,600 cu. ft. of gas and 120 ft. of water.

New operations.—Ten new operations were reported, all development wells. These included five in the Rangely field in Colorado, two by California Co., two by Idaho-Sharpless-Wasatch group, and 1 by Stanolind Oil & Gas Co. The new Wyoming operations were one each at Zimmerman Butte, Beaver Creek and Hamilton dome. The Zimmerman Butte well, Pacific Western Oil Corp. 75 Hilliar-Government, SE SW SE 35-44n-93w, will be of especial interest as it is nearly ½ mile southeast of that company's recent discovery in the Embar and will be the second well to that horizon. The Beaver Creek well is Stanolind 3 Unit, C NW NE 14-33n-96w, ¾ mile southeast of No. 2 and 1½ miles southeast of the discovery, these being gas wells in the Dakota and Morrison sands. Montana had two new operations, both in Kevin-Sunburst.

Completions.—Ten wells were completed,

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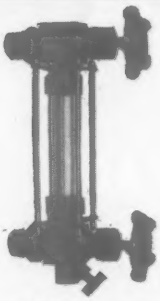

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of which 7 were oil wells with initial production of 2,122 bbl., and 3 were dry holes. These were distributed 2 oil wells for 920 bbl. in the Rangely field and 1 dry hole in Colorado; 4 oil wells for 1,167 bbl. in Wyoming, one each in Little Buffalo Basin, East Lance Creek, Byron and Mahoney fields; 1 oil well for 35 bbl. in Cut Bank and 2 dry holes in Kevin-Sunburst in Montana.

COLORADO SUCCESSFUL OUTPOST

Rangely, Rio Blanco County: Algord Oil Co. 1 Guiberson, C SE NE 18-2n-102w, TD 6,575 ft., top of Weber 6,334 ft., flowed 518 bbl. in 24 hours, cutting 6 per cent salt water, later subsequently dropped to 3 per cent.

COLORADO WILDCAT FAILURE

Christy, Pueblo County: Continental Oil Ct. 1 Paige, SE NW NW 6-18s-64w, dry, 6,929 ft. in schist, top Pennsylvanian 6,705 ft.

CALIFORNIA

Test Due on Area Near Los Angeles Airport

LOS ANGELES.—The Los Angeles City Council by adopting an ordinance creating a drilling district of 900 acres adjacent to the city's airport about 1 mile northwest of the El Segundo field has enabled a group of operators to drill a joint test in the near future.

In order that work will not interfere with use of the airport, derricks must be removed on completion of drilling and other facilities must be at a low level. The property is a part of the Sausal Redondo ranch which was purchased in 1937 by Richfield Oil Corp., Shell Oil Co., Inc., Standard Oil Co. of California, The Texas Co., Tide Water Associated Oil Co. and Union Oil Co. of California. This group paid approximately $900,000 for the 1,300 acres.

The city of Los Angeles, desiring to enlarge Mines field, was given an option recently to purchase 900 acres from the group for $970 per acre, exclusive of subsurface rights. To condemn this acreage, the city would have had to pay approximately $1,500 per acre in the present market, and it was decided to take advantage of the group's offer which stipulated that one or more tests could be drilled. The area is approximately midway between the Playa Del Rey field and El Segundo field. In both of these fields, production is found in the schist-conglomerate basement.

Elk Hills continues to hold attention due to development work by the Navy, Standard of California, and several drilling contractors. Navy's 44-24-Z in the west end of the Hillcrest section of Elk Hills is expected to be completed shortly. The Department's latest completion, 337-34-S, is permitted to flow only about 350 bbl. daily, but it flowed for a short time at a daily rate of 3,000 bbl.

The importance of the discovery of Independent Exploration Co. north and west of Sheep Springs field is not yet clear. This is one of the few wells in this district that has found the Carneros productive, and subsequent drilling may prove the existence of a substantial accumulation. Independent Exploration Co. expects the area to be highly productive and has taken extensive leases.

Of interest to operators in the Cymric field of Kern County is the formation test made by Superior Oil Co. in 77-22 Woody which went directly from Santos into the Kreyenhagen and cored top of the Point of Rocks sand at 5,038 ft. The test of the Point of Rocks sand from 5,052-5,100 ft. resulted in a gas blow of approximately 6,000,000 cu. ft. daily with no recovery of oil. A string of 7-in. casing was cemented at 5,038 ft. and this sand is now being tested.

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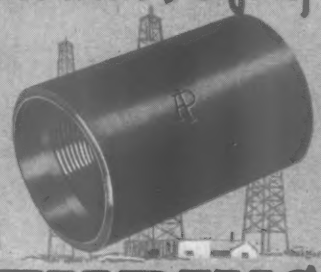

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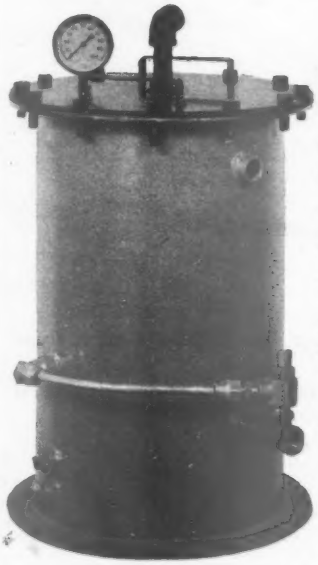

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Superior has withheld all data below the Oceanic sand in a previous completion on this lease but is generally credited with having cored a good oil sand in the Eocene. In the southern Cymric area, Union found the Point of Rocks sand barren in 65-26 Anderson.

New locations made this week exactly equaled completions. Work was slowed up for several days early in the week due to rains in wildcat areas. Drilling in proved fields where paved roads are available proceeded without delay. Shell has indicated it is not satisfied with the recently completed Dominguez Estate well east of the Dominguez field and has started additional testing. After being taken off production, this well was plugged back from 10,478 ft.—8,100 ft. Continental Oil Co. has started a test on the eastern edge of southern San Joaquin Valley in the Cottonwood Creek area of Kern County. This will be a Vedder sand test.

CALIFORNIA WILDCAT COMPLETION

Kern County, Sheep Springs West: Independent Exploration Co. 2 Temblor, 17-29s-21e, flow 1,500 bbl. 17.9°-gravity, 3 per cent cut, 64/64-in. bean, pressures 275/375 lb., TD 2,828 ft., Perf. 2,790-2,828 ft., top brown shale 1,443 ft., top Carneros sand 2,790 ft., probable new discovery, name of area tentative.

CALIFORNIA WILDCAT FAILURES

Kern County, Round Mountain: Miller & York 2 Kern County Land, 13-28s-28e, bottomed in very tight oil sand, top Pyramid Hills sand 2,210 ft., top Vedder sand of Miocene age 2,309 ft., Vedder sand too tight to produce, TD 2,348 ft.

Kings County, Pyramid Hills: Pyramid Production Co. 1 Spreckles, 16-24s-18e, bottomed in gray sand, had some encouragement but sand would not produce commercially, TD 4,214 ft.

Ventura County, Hopper Canyon: Union 1 Moran, 1-4n-19w, bottomed in barren gray sand, no important showings logged, TD 7,663 ft.

Timber Canyon: Standard 1 Toland Community, 18-4n-20w, bottomed in hard gray sand, only minor showings logged, TD 9,120 ft.

MICHIGAN

Michigan Operations Show Slight Gain

SAGINAW.—With 11 new locations set, completions for the week numbered 10 in Michigan, 4 oil producers, a gas well and 5 dry holes, 3 of those wildcat tests. Daily potential of the 4 oil wells was 2,100 bbl., most of it from another Deep River producer. New locations are scheduled for Wheatland and Big Rapids townships, Mecosta County; Coldwater and Isabella townships, Isabella; Elba of Gratiot, Douglass of Montcalm, Osceola of Osceola, Alamo of Kalamazoo, Geneva of Van Buren, Heath of Allegan, and Fraser of Bay.

Consumers Power Co. is dickering with Texas Panhandle for more natural gas, as much as 15,000,000,000 cu. ft. a year to be bought in the summer, stored in northern Michigan for the big winter demand. A 150-mile pipe line to the Ohio border figures in the negotiations.

MICHIGAN WILDCAT FAILURES

Allegan County, Cheshire Township: J. F. Reed 1 Fred Haven, NW NW NW 34-1n-14w, dry in Traverse lime, TD 1,300 ft.

Kent County, Algoma Township: Rex Oil Co. 1 Alvin Lemunyon, NE NE NE 8-9n-11w, dry in Monroe, TD 2,820 ft.

Newaygo County, Sherman Township: Daily Crude Oil Co. 1 L. and E. J. Ridderman, NE NE SE 18-13n-13w, dry in Dundee, TD 3,048 ft.

N. CENTRAL TEXAS

Bend Conglomerate Produces in Montague

WICHITA FALLS.—Youngblood & Foree 2 Joe Benton, A Lewis Survey, opens a new Bend conglomerate pool 3 miles northwest of Stoneburg in western Montague County. The well flowed 67 bbl. of 40°-gravity oil in 30 minutes through a ½-in. tubing choke. Production is from 6,132-42 ft. It has been shut in pending official test. The discovery is 3¼ miles northwest of the Johnson pool. Continental Oil Co. 1 Harvey, Block 2880, TE&L Survey, wildcat 4 miles west of Bowie, southwestern Montague County, is dry at 7,075 ft. after drill-stem test of the Ellenburger from 7,029-65 ft. failed to recover any shows.

Magnolia Petroleum Co. 1 Steele, Section 307, Block A, H&TC Survey, wildcat 7 miles southeast of Crowell, Foard County, on a 1-hour drill-stem test from 5,322-30 ft. recovered 30 ft. of 37.5°-gravity oil and 80 ft. of oil-cut drilling mud. It was drilled to 5,682 ft. in the Ellenburger and was preparing to take a drill-stem test. Standard Oil Co. of Texas 1 Mitchell, J. B. McNair Survey, northern Grayson County wildcat 2 miles north of Sherman, was drilling below 6,977 ft. in shale.

Electra field, Wichita County, had seven completions this week: KMA field, Wichita County, four; Holliday field, Archer County, three, and Wilson field, Cooke County, and Hildreth field, Montague County, two each. Wilson field had four locations and Knox field, Young County, and Sivells Bend field, Cooke County, three each. Cooper field, Archer County, and

(Continued on page 308)

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When builders add up the comparative costs of materials and labor, they find they can have sturdy steel construction for less money, with a plus element of flexibility. Thus, 2+2=5

This "Multiple-T" hangar embodies qualities which satisfy the most optimistic planner while placating the conservative element as well. For example, the four unit hangar can be assembled in 150 man hours of erection labor, a saving of up to two-thirds over similar types of construction. When the unpredictable needs of the future demand, additional units may be added at a fraction of the initial cost.

The same standards of stability will be found in this hangar as are inherent in all Star units

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ILLINOIS

Extension Well May Link Maple Grove and Bennington

MATTOON.—The Maple Grove field of Edwards County has been extended ½ mile to the southwest with the completion of H. C. Hageman et al 1 A. Koenecke, NW SW NW 16-1n-10e. Following an acid treatment of 5,000 gal., the well flowed at the rate of 1,000 bbl. of oil daily from the McClosky lime at 3,304-16 ft., total depth. It is now flowing from 500 to 600 bbl. daily through a 1⅛-in. choke. The 1 Koenecke is approximately midway between the Maple Grove and Bennington fields, and additional drilling may eventually link the two since both are producing from the McClosky.

Another large well is indicated for the Clay City Consolidated field in the Olson Drilling Co. 1 E. Lewis, E½ NE SE 36-2n-8e. The 1 Lewis is now on production test of the Rosiclare at 3,068-78 ft., total depth. After an acid treatment, the well flowed 1,108 bbl. of oil in 24 hours.

Illinois completions during the past week totaled 35, of which 19 were oil wells and 16 were dry holes. The Mattoon field continued its lead with eight completions reported. Five wildcats were completed and all were dry.

New operations totaled 32 and included 6 wildcats located in Jasper, Clinton, Cumberland, Hamilton, Bond and Wayne counties. New field operations included five each in Coles, Wayne, Richland and White counties. The Mattoon field continued to hold its lead in active operations, although this lead is beginning to decline as the field is nearing its limit of development.

ILLINOIS WILDCAT FAILURES

Christian County: M. H. Richardson 1 C. Augur, SE NW SE 14-15n-2w, dry at 1,907 ft., Barlow 798 ft., Cypress sand 817 ft., Aux Vases sand 857 ft., Ste. Genevieve 915 ft., Rosiclare 923 ft., Chattanooga 1,833 ft., Devonian 1,895 ft., slight show oil.

Cumberland County: Ben Nation 1 Phipps, NE SW NW 27-11n-7e, dry at 2,141 ft.

Morgan County: J. I. Darst 1 C. Thornley, SE SE SE 3-16n-11w, dry at 1,035 ft.

White County: R. J. Fryer 1 McClanahan, SW SW SW 28-4s-9e, dry at 3,433 ft., Kincaid 2,078 ft., Palestine 2,338 ft., Menard 2,439 ft., Vienna 2,556 ft., Tar Springs 2,575 ft., Glen Dean 2,688 ft., Hardinsburg sand 2,744 ft., Golconda 2,786 ft., Barlow 2,913 ft., Paint Creek 3,025 ft., Benoist sand 3,104 ft., Aux Vases sand 3,215 ft., Ste. Genevieve

(Continued on page 308)

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OKLAHOMA

Keyes Field Receives Southeast Extension

THE Keyes pool of Cimarron County assumed added importance during the early part of the past week with the report that Pure Oil Co. 1 Jermyn, SW SW SW 18-5n-8e, flowed at the rate of 404 bbl. of oil and 2,200,000 cu. ft. of gas in 21 hours during preliminary tests. Production was through 5½-in. casing and was cut slightly with mud and salt water.

The 1 Jermyn is 1¼ miles southeast of the 1 Johnson, which pumped 505 bbl. per day, and is 1¾ miles southwest of the 1 State, discovery oil well of the area. The new producer, drilled to a total depth of 4,906 ft., was plugged back to 4,892 ft. and casing was set at 4,870 ft. Production is from the Cherokee sand (basal Pennsylvanian).

Pure 1 Sparkman, NE NE NE 3-5n-8e, about 4¾ miles northeast of the 1 State, showed only a small volume of gas when bailing and is shut down waiting on cable tools. Casing is set at 4,715 ft. and hole is bottomed at 5,015 ft. The 1 McCoy, NW NW NW 2-4n-8e, several miles to the southeast of the producing wells, has been reported as dry at a total depth of 4,845 ft.

Pure has announced two new locations in the Keyes district and cellars are being dug at both of these. They are the 1 Mackey, NE NE SE 13-5n-7e, and the 1 McKirahen, NE NE NE 13-5n-7e.

W. N. Dunn 1 Walker, NE NE SW 30-14n-10e, Creek County, has apparently opened a new pay zone for the Tuskegee pool with the recovery of oil and gas from the Dutcher sand. Saturation was encountered at 2,944-54 ft. and a drill-stem test made gas in 3 minutes and 1,500 ft. of oil through a ½-in. choke. Operators estimated the fillup at the rate of 20 bbl. an hour. Pipe has been set and storage will be erected before plug is drilled for retesting.

Oklahoma fields leading in active development operations at the present time are the Cement field with 31 rigs running, West Edmond with 26, and the Moore fields with 20. Many areas throughout the state are receiving concentrated development with Stephens and Seminole counties leading in the older areas.

OKLAHOMA SUCCESSFUL WILDCAT

Garvin County: Vickers Petrol and Globe 1 Gibson, SE NE 30-3n-2w, flowed 57 bbl. from sand at 6,541-64 ft.

OKLAHOMA WILDCAT FAILURES

Garfield County: Stephens Petroleum Co. 1 Kaiser, SW SW NW 7-20n-3w, dry at 6,710 ft., Arbuckle 6,496 ft.

Jefferson County: Bridewell Oil & Gas 1 Lena Seay, NW NE SE 16-6s-6w, dry at 2,598 ft.

Love County: W. F. Turner 1 fee, SE SE

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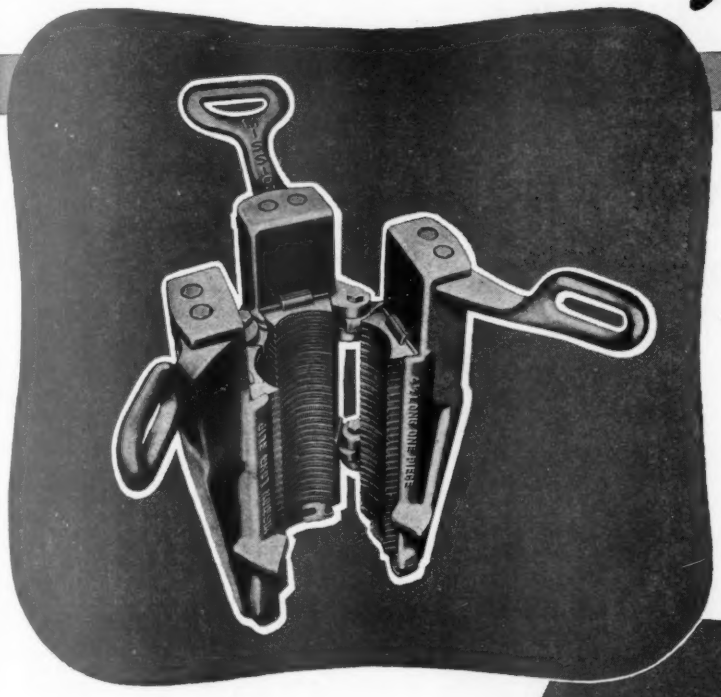

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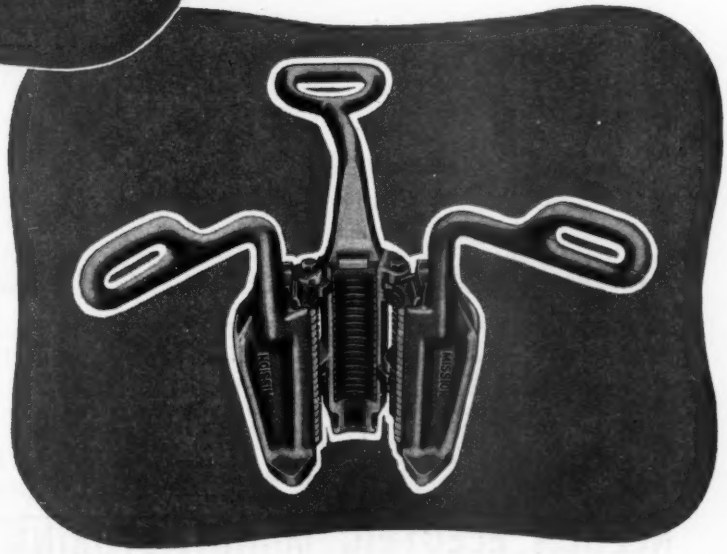
When slips are dropped in bowl, the dogs roll upward slightly. When the load is being taken by the slips, the dogs roll downward to grip the pipe firmly.

Instant Release

When the load is being taken off the slips, the dogs roll upward and away from the pipe — releasing the pipe and freeing the slips from the bowl.



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SE 27-7s-1w, dry at 5,800 ft., Beekmantown sand 5,730 ft.

Payne County: British American 1 Gibson, NW SE SW 8-17n-2e, dry at 4,917 ft., second Wilcox 4,903 ft.

Stephens County: Richek Oil Co. 1 Nichols, SW NW NW 24-2s-5w, dry at 1,501 ft., sand 664-70 ft.

Continental 1 Wilson, SE NE SW 28-2s-4w, dry at 5,009 ft., shale 5,006-09 ft.

LA.-ARK.

Three Wells Drilling Ahead in Benton Area

SHREVEPORT.—With three wells drilling ahead, prospects of enlarging the Benton area in Bossier Parish look promising. Casing is being run to test a show at 8,245 ft. at the Grady H. Vaughan et al 8 Benton, 1,980 ft. from north line and 1,993 ft. from west line of 13-20n-13w. Barnsdall Oil Co. & Sohio Petroleum Co. 9 Benton, 2,008 ft. from the south line and 2,010 ft. from the east line of 6-20n-12w, is drilling below 7,821 ft. and their 10 Benton, E½ SE 21-20n-12w, is drilling below 5,630 ft.

Arkansas-Oklahoma Gas Co. 1 N. C. Biggs, NE NW 7-7n-27w, wildcat in Logan County, Arkansas, has been drilled to 3,634 ft. Operators are fishing for 7-in. pipe.

Operations have begun on two wildcats in Arkansas. One is the 1 Southern Co. & Sturgis Brothers, SW SE SE 26-9s-16w, in Dallas County. The other is the C. A. Kinard 1 McCauley, NE SW 14-12s-6w, in Drew County.

No completions were reported from Arkansas. North Louisiana had 13 completions. Four wildcats, two in Richland Parish, one in Concordia Parish and one in Madison Parish, were dry. Seven of nine field wells completed were oil and two were dry.

NORTH LOUISIANA WILDCAT FAILURES

Concordia Parish: S. W. Richardson A-1 Madison, 960 ft. south and 1,980 ft. east of northwest corner of 34-6n-9e, dry at 10,602 ft.

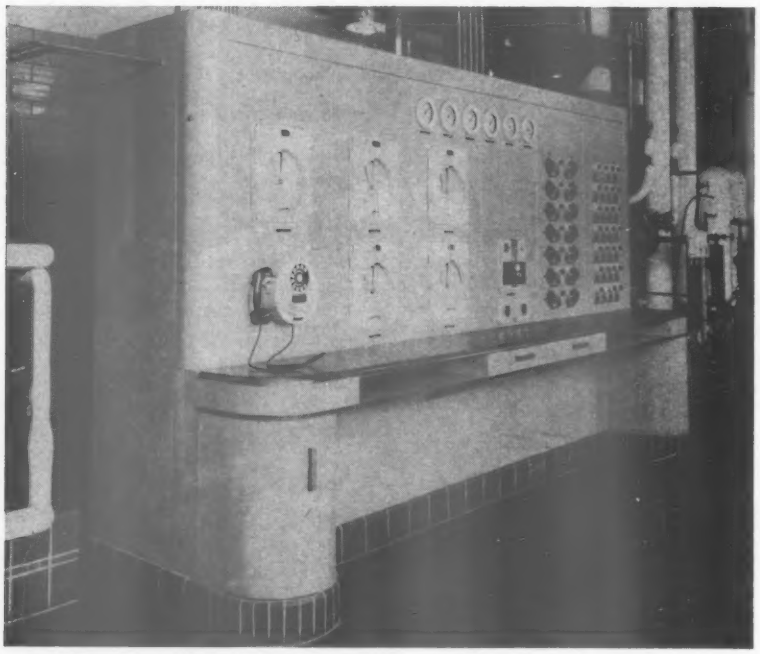
Madison Parish: S. W. Richardson 1 F. Hooten, SW NE 31-18n-12e, dry at 4,740 ft.

Richland Parish: Big Chief Drilling Co. 1 George B., 665 ft. west and 465 ft. north of southeast corner SW SE 7-17n-9e, dry at 4,818 ft.

Humphrey-Winn et al 1 M. D. Boughton, 990 ft. north and 330 ft. east of southwest corner of 36-16n-6e, dry at 3,660 ft.

EXPLOSION RESISTING

Refinery Control Panels



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OHIO, KENTUCKY

Bethlehem Township Gas Pool Extended ½ Mile

COLUMBUS.—East Ohio Fuel Co. 1 N. E. Shearer, Section 3, extends the gas pool in northeast Bethlehem Township, Stark County, more than ½ mile west. White Clinton from 4,452 to 4,476 ft. was shot and shut in at 1,118,000 cu. ft.

In the Canton area Brendel et al 1 Fred Addessi, Section 29, Plain Township, Stark County, gaged 3,372,000 cu. ft. natural. East Ohio 1 M. R. Schneider, Section 32, was shot and shut in at 1,625,000 cu. ft.

In the Middle Wellington pool, Ohio Fuel 1 Howard Hacker, Lot 6, gaged 2,520,000 cu. ft. from the top Clinton at 2,380 to 2,395 ft.

Two Medina sand producers and two Clinton gas wells were completed in Salt Creek Township, Muskingum County.

Frank Lyons 1 A. B. Wright, Clinton test in Section 10, Hanover Township, Columbiana County, is drilling in the Clinton with some good shows of gas. Top of the Clinton was found at 5,766 ft.

A record number of 49 locations were reported this week. Stewart had 15, mostly in the Hemlock Grove pool. Lancaster had 12, Ashland 8, Brush Creek 6, and Cambridge and Mt. Vernon 4 each. Ashland led with 7 of the 21 completions.

SUCCESSFUL WILDCAT COMPLETIONS

Muskingum County, Newton Township: Pure Oil 1 H. C. Eppley, Sec. 26, Clinton 3,417-3,444 ft., 2,390,000 cu. ft., TD 3,474 ft.

Washington County, Decatur Township: Ohio Fuel 1 F. A. Grubb, Fr. 32, Maxon 1,208-1,226 ft., 104,000 cu. ft., TD 1,226 ft.

UNSUCCESSFUL WILDCAT COMPLETION

Medina County, Granger Township: Ohio Fuel 1 Dominick Testa, Lot 15, Clinton 3,502-3,518 ft., TD 3,592 ft.

EASTERN KENTUCKY

ASHLAND.—A check of operations in the eastern Kentucky field for the past week reveals 1 completion for approximately 100,000 cu. ft. of gas and a drilling well which is showing for a good producer.

Kentucky-West Virginia Gas Co. completed well No. 801 on the J. S. Cline property in Pike County, total depth 3,521 ft., daily open flow of 84,000 cu. ft. of gas in shale and 15,000 cu. ft. in Big Lime.

WESTERN KENTUCKY

OWENSBORO.—Carter Oil Co. 1 George Nally, 25-P-21, in the Waverly North pool of Union County, is showing for the best well drilled in the Western Kentucky area in several weeks. Following a 5,000-gal. acid treatment, the well flowed 512 bbl. of oil in 15 hours through perforations at 2,600-18 ft. It was then perforated at 2,574-84 ft. and flowed 125 bbl. in 3 hours. Total depth is:

(Continued on page 303)

KANSAS

New Pool Opened In Rooks County

SUCCESSFUL completion of the Bird & Boreing 1 Veverka, SW SW 27-8-19w, has opened a new pool for Rooks County. The well has been pumping 10 bbl. of 24° gravity oil an hour. It has not been acidized and a potential test will be taken soon. The pool opener, located 1½ miles north of the Barry pool, has been designated as the discovery well of the Webster pool by the Kansas nomenclature committee.

Darby-Bothwell 1 Glass, NW NW SW 30-11-19w, a wildcat in Ellis County, had a slight oil show at 3,305-11 ft. The Topeka was topped at 3,119 ft. and the Lansing at 3,376 ft. Drilling is being continued below 3,410 ft. The well is located about 1 mile southwest of the Solomon pool in Ellis County.

Production in the Ellis pool, Ellis County, has been extended ½ mile to the east by the Doley Oil Co. 1 Huber, SW SW SW 32-12-20w. The well was completed with a state potential of 35 bbl. a day. Pay zone is the Arbuckle at 3,819 ft.

Kansas reported 35 completions. Of the three wildcats completed, one was successful and two were dry. Field wells totaled 32 with 20 oil, 5 gas, and 7 dry.

KANSAS SUCCESSFUL WILDCAT

Butler County: Nadel & Gussman 1 Crowley, SW SW SE 18-28-5e, 100 bbl. oil from Bartlesville sand at 2,695-738 ft., TD 2,738 ft.

KANSAS WILDCAT FAILURES

Barton County: B & R 1 Cochrane, SE SE SE 5-17-13w, dry at 3,430 ft., Arbuckle 3,400 ft.

Sheridan County: Continental Oil Co. 38 Strat (McWilliams), NW NW NW 32-9-26w, dry at 3,968 ft.

MISSISSIPPI

Another Salt Dome Proven In Eastern Copiah County

JACKSON.—Another salt dome has been discovered in Copiah County in drilling the Stanolind Oil & Gas Co. 1 T. A. Huntington, NW SE 28-1n-1w. After circulation was lost at 1,647 ft., the well was completed as dry at 1,650 ft. Samples taken at 1,410 ft. contained pyrite and lime and the anhydrite was topped at 1,640 ft.

No shows have been reported from tests at the Humble Oil & Refining Co. 3 Harry Stover et al, 1,300 ft. south and 458 ft. west of northeast corner of 20-3n-7w, wildcat in Greene County. Drilling is being continued below 8,760 ft.

There were four completions in Mississippi. Two wildcats, one in Lincoln County and the other in Marion County, were dry. The wildcat in Warren County was completed as a gas well. Brookhaven field added a producer with an initial production of 97 bbl. in 24 hours.

MISSISSIPPI SUCCESSFUL WILDCAT

Warren County: Magnolia Petroleum Co. 2 Ruth Pidgeon, east of southwest corner of SE SE 27-17n-4e, flowed 7,200,000 cu. ft. of gas from sand at 2,037-47 ft., TD 2,546 ft.

MISSISSIPPI WILDCAT FAILURES

Lincoln County: Danciger Oil & Refining Co. 1 Central Lbr. Co., 660 ft. north and 1,980 ft. east of southwest corner of 22-8n-5e, dry at 10,673 ft., Marine Tuscaloosa 10,210 ft.

Marion County: Humble Oil & Refining Co. 1 W. E. Walker, SW SE 25-2n-18w, dry at 9,657 ft.

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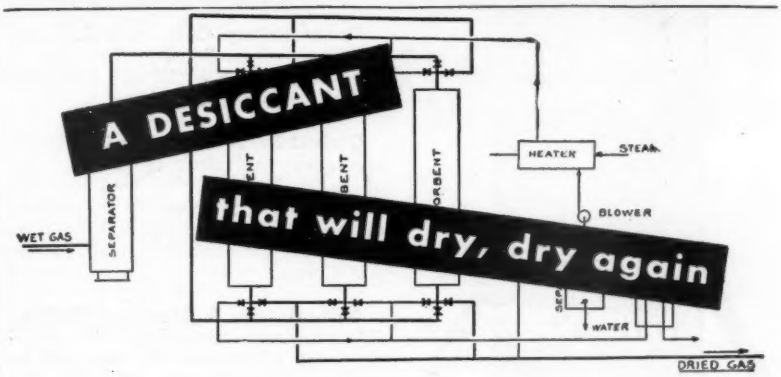

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Among the Drilling Contractors

Sam P. Daniel has sold his interest in **Daniel Drilling Co.** to E. A. Rumler, who has changed the name of the firm to **E. A. Rumley Drilling Co.**, with headquarters in Oklahoma City.

A. R. Sarver Drilling Co. has been contracted by E. C. Dailey to drill the 1 Franks, Tissue, Cole, in SE NE NE 6-10n-5w, Crystal pool, Montcalm County, Michigan.

Commonwealth Drilling Co., Calgary, Alta., has drilling contract on an exploratory well for California-Standard in southeastern Alberta, south of Irvine and southeast of Medicine Hat, where California-Standard has acquired holdings of 58,433 acres. This is an entirely new area for development.

Philco Drilling Co., with capital of $100,000, has been organized at Oklahoma City, by Phil A. Cornell, Glenna J. Cornell, and A. D. Howell.

Union Rotary Corp. will drill the Michigan Consolidated Gas Co. 1 Ensch-Classon, SW SE SE 4-15n-9w, Mecosta County, Michigan.

Corbett-Barbour Drilling Co., Tulsa, announces the return from the Army of A. M. Barbour, Jr., who will resume his old post as vice president of the firm. Barbour spent 30 months in the meteorological branch of the Air Corps.

Goll, Graves & Mechling Drilling Co. has the contract to drill the 8 Emanuel Klenk, in NE SE NW 8-19n-4e, Arenac County, Michigan, for Basin Oil Co. and Don Rayburn. The well is in the Deep River field.

Olsen-Blount Drilling Corp., Oklahoma City, was cleaning out and testing the Culbertson-Irwin 1 Gutman, in C SW NE 18-24s-37e, in the Langlie-Mattix field of Lea County, New Mexico. Total depth is 3,591 ft. In the same county the contractor has staked location and was moving in tools on the Olsen-Blount Drilling Corp.-Western Gas Co. B-1 Eaton, in C SW NW 12-25s-37e.

Double R Drilling Co. has been granted state charter with $99,000 authorized capital, by Oklahoma Corporation Commission. Incorporators are Robert M. Jordan and T. L. Dennis, Oklahoma City, and Ray J. Griffith, of Shawnee, Okla.

Leonard Drilling Co. will drill the Rowmor Corp. 1 Mike and Mary Skoropada, SE SW NW 9-13n-10w, Tuscola County, Michigan.

Makin Drilling Co., with headquarters in Hobbs, N. M., will operate in the Permian basin. The new firm is headed by R. S. "Cotton" Makin, formerly with **Trinity Drilling Co.**

Merridith & Higginbotham Drilling Co. will drill a wildcat in Iosco County, Michigan, for Ray W. Matlock and T. H. Welch. The well is the 1 John C. Johnson, NE NW NE 1-22n-8e.

Regent Drilling Co., Ltd., Vermilion, Alta., has recently signed a contract to drill four wells for Canadian Industries, Ltd., at Sandwich, Ontario, just outside of Windsor. Con-

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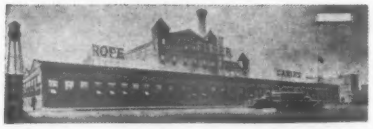

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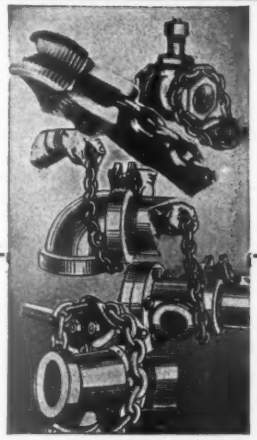

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tractor is also rigging up a new Cardwell rig at Wardlow, Alta., for British American and Standard of California, to test the Devonian and possibly the Ordovician.

Lohman & Johnson Drilling Co. will drill the Clarence Wood 3 S. G. Hardiman, SW NE 27-1s-12w, in Gibson County, Indiana.

Dee Drilling Co. has the contract to drill the 1 Parkinson, SE NE NW 24-1s-12w, for Illinois Mid-Continent Co. in Gibson County, Indiana.

Johnson Brothers Drilling Co., Wichita Falls, has the contract to drill the Nail-Reed Oil Co. 1 C. C. Coyle, in NE NE NE 33-5n-12w, southwest of Apache, in Caddo County, Oklahoma. Original contract is for 2,500 ft., with a 1,600-ft. and 2,300-ft. sand to be tested first. If conditions warrant, the well may be drilled deeper.

Kentucky Fields

(Continued from page 300)

2,675 ft., and operators are continuing to test.

Four completions were reported for Western Kentucky, including two dry wildcats and two oil wells in Waverly North field. Two new tests were under way in Crittenden County and one each in Webster and Metcalf counties.

WESTERN KENTUCKY WILDCAT FAILURES

Henderson County: Delta Drilling Co. et al 1 Anna Lee Boswell, 7-P-26, elev. 2,332 ft., Menard 1,280 ft., Glen Dean 1,552 ft., Barlow 1,800 ft., Cypress sand 1,828 ft., Paint Creek 1,685 ft., Benoist 2,006 ft., Ste. Genevieve 2,114 ft., McClosky 2,247 ft., dry at 2,332 ft.

Mitchell 1 Thornberry, 5-N-23, elev. 500 ft., dry at 2,785 ft., Menard 1,842 ft., Glenn Dean 2,022 ft., Barlow 2,298 ft., Ste. Genevieve 2,634 ft., McClosky 2,247 ft.

INDIANA

EVANSVILLE.—The Carter Oil Co. 1 William Schisler, NW SW NW 13-7s-14w, shows prospects of extending the Jeffries pool of Posey County about two locations northeast. A 2-hour drill-stem test of the Tar Springs sand at 2,124-65 ft. recovered 180 ft. of gas, 200 ft. of oil and 30 ft. of oily mud, with no water showing. Previously, a 4-hour drill-stem test of the Waltersburg at 1,944-66 ft. recovered 925 ft. of oil and 925 ft. of salt water. Operators are drilling ahead at 2,440 ft.

Continental Oil Co. is drilling below 1,000 ft. at their 1-D Cooper estate, SW SW SW 13-3s-14w, a deep test in the Griffin pool of Gibson County. This well is scheduled to go to the Trenton, which is expected at about 6,200 ft.

A large gain in Indiana completions was noted during the past week with seven oil wells and two dry holes reported. One of the oil wells was a successful wildcat in Gibson County.

Three new operations each were reported for Gibson and Posey counties, with no other areas receiving any new development. The New Harmony field of Posey County and the North Owensville field of Gibson County maintained their lead in the number of active drilling wells under way.

INDIANA SUCCESSFUL WILDCAT

Gibson County: J. Kabana 1 Coleman Comm,. SW SW NW 7-2s-9w, elev. 450 ft., pumped 25 bbl., Rosiclare 1,792-98 ft., TD 1,969 ft.

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SEE COMPOSITE CATALOG PAGES 3101 TO 3120

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PERSONALS

Colorado Interstate Raises Brunston To New Post

G. F. BRUNSTON, new general superintendent of Colorado Interstate Gas Co., has been associated with the wholesale gas company since its organization 18 years ago.

Formerly general superintendent and chief engineer, Brunston was named to fill the vacancy caused by the death of J. P. McClintock. Before joining Colorado Interstate in 1928, he was with the Ford, Bacon, and Davis firm in New York and with the Interstate Natural Gas Co. in Monroe, La. He is a graduate with a mechanical engineering degree from Drexel Institute, Philadelphia.

C. B. Abbot, formerly assistant engineer, who also joined the Colorado company in 1928, is Brunston's successor as assistant general superintendent and chief engineer. Abbot, a Harvard engineering graduate, served with the Army Engineers in the first World War.

Glenn Hughes, drilling superintendent in the Texas Gulf Coast area for Sun Oil Co. has been named production superintendent for Oklahoma and Kansas with headquarters in Tulsa. He succeeds **M. L. Brown,** who was named assistant general production superintendent at Dallas.

Albert R. West, division engineer at Billings, Mont., for Carter Oil Co., has been made chief petroleum engineer in the Tulsa office. He was succeeded at Billings by **Max Sons,** formerly engineer at Tulsa for the company. Other changes in the Carter Oil organization: **Lewis W. Breeden,** senior petroleum engineer at Mattoon, Ill., to district engineer at Great Bend, Kans.; **William J. Lang,** seismograph party chief in Venezuela, transferred to Tulsa; **Billy D. Low,** party chief at Minden, La., transferred to Tulsa; and **Maurice V. Adams,** senior petroleum engineer in the Dix, Ill., district, transferred to Seminole, Okla.

Ralph E. Grimm, formerly assistant civil engineer for United Natural Gas Co. at Oil City, Pa., has been appointed superintendent of distribution for Iroquois Gas Corp. at Buffalo, N. Y.

H. H. Van Aken, former general manager of Permian Oil Co., has been elected vice president and general manager of Reserve Oil & Gas Co. in San Francisco.

Edward Pickett has resigned as San Joaquin Valley scout for Union Oil Co. and joined Wilshire Oil Co. as district exploration engineer in Bakersfield, Calif.

Steve Dixon, former head well puller for Shell Oil Co., Inc., in the Long Beach, Calif., field, has been promoted to field production foreman. **John F. Deliessegues,** an operator in Shell's Dominguez, Calif., natural gasoline plant, has been advanced to foreman and placed in charge of the company's absorption unit in the Brea Olinda plant.

John L. Bugg, formerly with United Gas Co. in Houston and in New Orleans where he was measurement superintendent, has started an engineering firm in Houston following his separation from the Navy.

A. H. Weil, superintendent of the gasoline and chemical departments of United Gas Pipe Line Co. and a former Army lieutenant colonel, has been awarded the Army Commendation Ribbon "for outstanding service in connection with the development of the atomic bomb." He was assigned to the atomic bomb project at Oak Ridge, Tenn., in August 1943 and served as assistant executive officer to the district engineer.

Bruce Robinson, who joined General Petroleum Corp. in 1925 as a timekeeper, has been advanced to assistant production manager. **Richard R. Shinn,** who joined the company in 1913, has been promoted to general superintendent of production.

P. H. Frankel, well-known petroleum economist of England who is associated with Manchester Oil Refinery, Ltd., has been visiting in New York, Houston, Dallas, Tulsa, and other points of the Southwest. He will return to England April 7.

William H. Rowland, Jr., former superintendent of Creole Petroleum Corp.'s La Salina refinery in Venezuela, has been appointed coordinator of a "Coin Your Ideas" program at Standard Oil Co. of New Jersey's Bayway refinery. This program involves a method of processing employes' suggestions.

E. Gamba-Escallon, engineer formerly on the Colombian Ministry of Oil staff and vice consul in charge of petroleum affairs in New York, has been appointed general manager of the Colombian Government enterprise, National Radio Communications.

Lawrence O'Donnell, chief mechanical engineer of the production department of Shell Oil Co., Inc., has been elected chairman of the Houston chapter of the American Petroleum Institute succeeding **R. E. Bridges,** division petroleum engineer of Humble Oil & Refining Co. **J. E. Bailey,** Tide Water Associated Oil Co., is first vice chairman; **Harold Decker,** Pan American Production Co., second vice chairman; and **Dudley Tower,** Union Oil Co. of California, secretary-treasurer. Directors are: **J. U. Teague,** Hogg Oil Co.; **W. T. Vietti,** The Texas Co.; **L. D. Cain,** Southern Drilling Co.; **L. E. Garfield,** Hughes Tool Co.; **Aubrey Schofield,** Gulf Oil Corp.; **George H. Calhoun,** Shell Oil Co., Inc., and **Ralph Graham,** Tennessee Gas & Transmission Co.

L. O'DONNELL

Dr. Henry Sonneborn III and **Dr. Hans Schindler** have joined the technical staff of the Daugherty refinery of L. Sonneborn Sons, Inc., at Petrolia, Pa. Dr. Sonneborn, until re-

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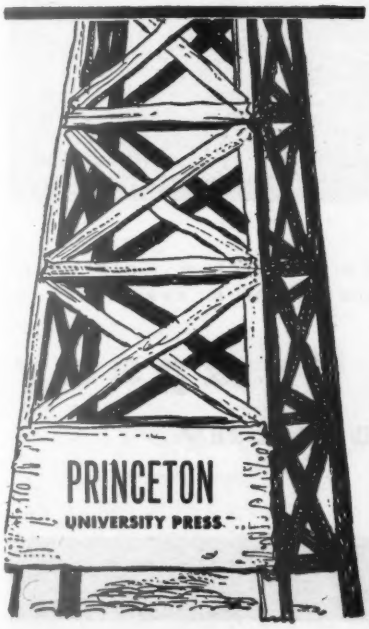

cently a Navy lieutenant serving as experiment and test officer at the Naval Ammunition Depot at St. Juliens Creek, Va., will be assistant to **Dr. F. W. Breth,** vice president and technical director. Dr. Schindler, formerly senior research chemist at the research and development laboratories of Pure Oil Co. at Winnetka, Ill., will be research chemist at Petrolia. He recently served on the technical oil mission which investigated the German petroleum industry.

R. C. Brown, associated with Continental Oil Co. since 1924, has been named assistant to **J. C. Johnston,** Denver regional manager of the production and drilling department of the company.

Thornton Davis, Peerless Oil & Gas Co., San Antonio, has been elected president of the South Texas Geological Society. Other new officers include **Marion J. Moore,** Transwestern Oil Co., vice president; and **Paul B. Hinyard,** Shell Oil Co., Inc., secretary-treasurer.

LEGAL

U. S. DEPARTMENT OF THE INTERIOR, General Land Office, Washington 25, D. C. Notice is hereby given that sealed bids will be received until noon on Monday, April 15, 1946, for land described herein situated within the known geologic structure of the Moffat Oil Field, Colorado. This land is offered to qualified bidders of the highest cash amounts per acre as a bonus for the privilege of leasing the land under section 17 of the leasing act as amended by the Act of August 21, 1935 (49 Stat. 674, 30 U.S.C. sec. 226), in the following parcels: T. 4 N., R. 91 W. Parcel No. 1, sec. 9, lots 7 and 8, 69.50 acres. Parcel No. 2, sec. 11, lots 6, 7, 8, 9, 10, 15, 16, 187.89 acres. Parcel No. 3, sec. 15, lots 1 and 8, 73.78 acres. Parcel No. 4, sec. 15, lot 5, 38.91 acres. T. 5 N., R. 91 W., Parcel No. 5, sec. 27, lot 15, and lots 13, 16, 17, 18, 21 in Tract 53; sec. 34, lots 2, 4, 6, 9 in Tract 53, 160.19 acres. Parcel No. 6, sec. 28, lots 4, 5, 6, 7, 8, 165.53 acres. Parcel No. 7, sec. 29, lots 1, 2, 7, 8, 9, 14, 206.10 acres. Parcel No. 8, sec. 32, lots 5 and 6; sec. 33, lots 4, 5, 13, 14, 114.15 acres. Parcel No. 9, sec. 33, lots 1, 2, 3, 7, 167.81 acres. Parcel No. 10, sec. 34, lots 8, 10, 12, 85.99 acres. Parcel No. 11, sec. 34, lots 15, 16, 21, 22, 157.50 acres. Parcel No. 12, sec. 35, lots 3, 4, 6, 7, 8, 11, 12, 13, 14, 15, 16, 449.22 acres. Total 1,876.57 acres. Bids must be submitted on each parcel separately, but if two or more parcels are awarded the same bidder, they may be included in a single lease, provided the combined acreage does not exceed 640 acres. Each bidder must submit with the bid one-fifth of the amount bid in cash, or by certified check made payable to the order of the Treasurer of the United States, and file the showing of qualifications to receive a lease, required under 43 CFR 192.19. The envelopes should be plainly marked "Bid for Parcel No. ..., Moffat Oil Field. Not to be opened before noon, Monday, April 15, 1946." No bids received after the hour fixed herein for the opening of bids will be considered. The remainder of the bonus and the annual rental at the rate of $1 per acre must be paid and a $5,000 corporate surety bond must be furnished by a successful bidder prior to the issuance of a lease. The deposits of the other bidders will be returned upon acceptance of the successful bids by the Secretary of the Interior. The successful bidder will be required to agree not to discriminate against any employee or applicant for employment because of race, creed, color, or national origin, and to require an identical provision to be included in all subcontracts. Bidders are warned against violation of section 59, U. S. Criminal Code, approved March 4, 1909, prohibiting unlawful combination or intimidation of bidders. The right is reserved to reject any and all bids in the discretion of the Secretary of the Interior. Fred W. Johnson, Commissioner.

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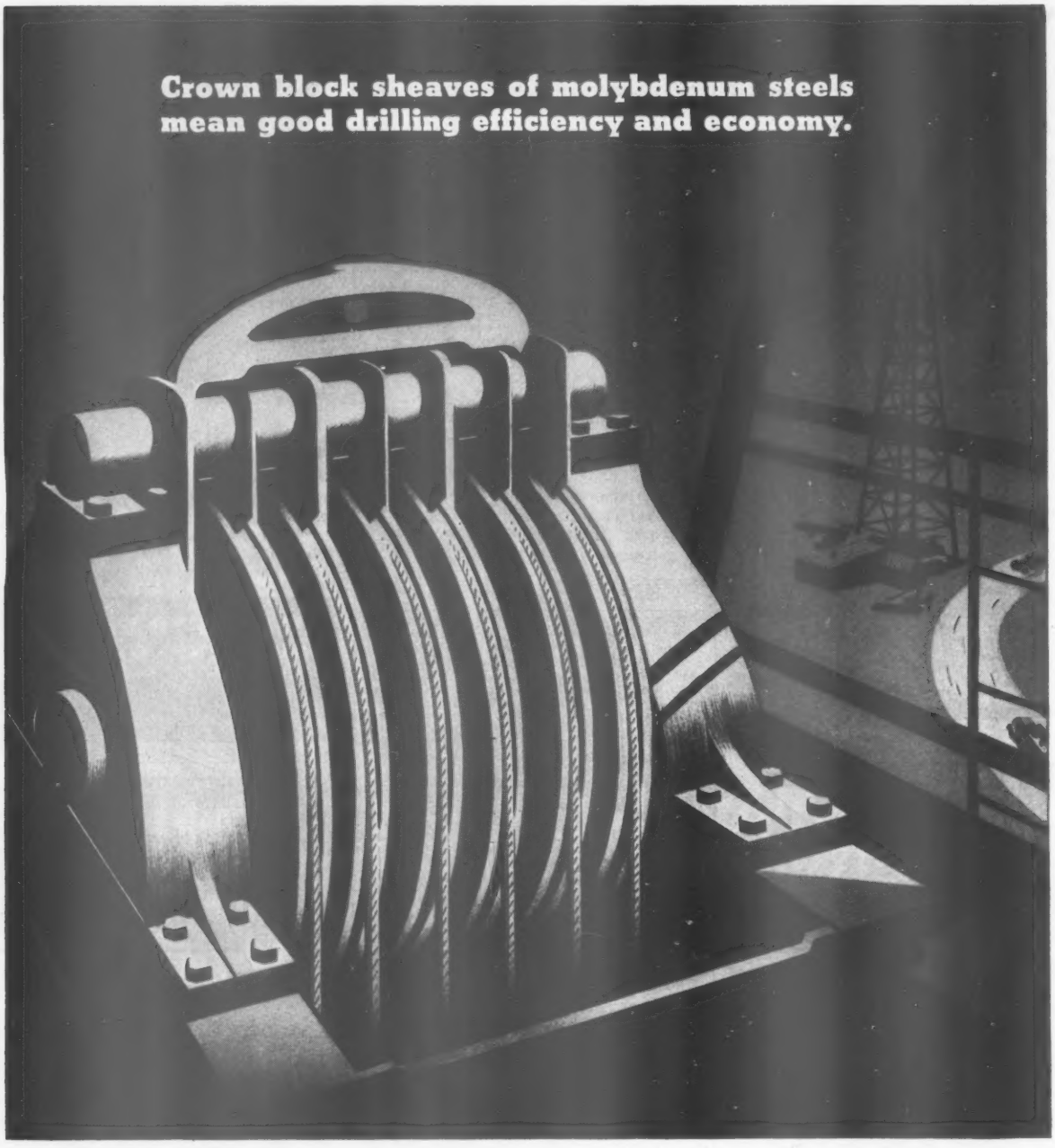

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MOLY

Equipment Men in the News

Two Join Cummins Service and Sales

Sales representatives Edward M. Bonette and James R. Neal have joined the staff at Cummins Service and Sales, 1661 Mc-

JAMES R. NEAL *E. M. BONETTE*

Garry Street, Los Angeles. Specializing in transportation and industrial-engine installations, Bonette will cover territory north from Los Angeles to Santa Maria. Neal will be is charge of the district south to San Diego.

Bonette was connected with the International Harvester Co. for 13 years as a general line "blockman" and parts manager of the Los Angeles branch. Neal comes to the Cummins Sales organization direct from a 3-year hitch in the Navy. Previously has was associated for 9 years with Euclid Road Machinery Co. of Cleveland as a chief inspector and field representative.

Olson Appointed Link-Belt District Manager

A. J. OLSON

Arthur J. Olson, heretofore district sales engineer for Link-Belt Co. at Chicago, has been appointed district sales manager at Kansas City, to succeed Max Giffey, who has resigned after 40 years' service. Olson has been in the employ of Link-Belt since 1918, at the Pershing Road plant in Chicago. He will be assisted in his new position by J. Arthur Townsend and Leroy C. Rathsam, district sales engineers.

Parks Named Jessop Sales Manager

Robert A. Parks has been named general sales manager of Jessop Steel Co., Washington, Pa. He was formerly district manager for Jessop in Washington, D. C.

Slottman Heads New Division Of Air Reduction Co.

C. D'W. Gibson, vice president in charge of sales for Air Reduction Co., New York, has announced the organization of a new technical sales division of the firm. The new division is headed by Dr. George V. Slottman, with the company 10 years. S. D. Baumer and E. V. David, who have been assistant managers of the applied engineering department, are assistant managers in the new sales division.

Bank Officials Named

Joe A. Clarke, formerly vice president and cashier, First National Bank, Albany, Tex., has been elected vice president of the Fort Worth National Bank. W. C. Dietz and W. H. Peterson, formerly assistant vice presidents, have been elected vice presidents, and H. H. Harp and B. P. McDonald have been appointed assistant cashiers. O. D. McCaulley has been appointed assistant trust officer.

Columbia Chemical Moves

Executive offices of the Columbia Chemical Division, Pittsburgh Plate Glass Co., are now located at Fifth Avenue and Bellefield, Pittsburgh. These temporary quarters have been necessitated by lack of sufficient space at the former address to accommodate personnel returning from military service and other expansions.

Westinghouse Elects Two Officers

Westinghouse Electric Corp., Pittsburgh, has announced election of Gwilym A. Price as president, succeeding George H. Bucher, resigned. Under a recent amendment of the corporation's bylaws, Price as president will be the chief executive officer.

L. E. Osborne, who joined Westinghouse at the age of 16 as a clerk in the tool room at the East Pittsburgh Works, has been named senior operating vice president.

Butler to Open Denver Offices

Samuel Butler, head of the petroleum products division of Sharples Research and Engineering Laboratories, of Philadelphia, is in Denver to open division headquarters and will employ a staff of 20 experts to work in the Rangely field.

Century Building New Research And Development Laboratory

The Century Manufacturing & Instrument Co. has just begun construction on a modern type building to house its research and development laboratory at 1400 North Utica Avenue, Tulsa. This building will be headquarters for the offices and laboratories of the Century company, headed by W. E. Morrow, which will develop and manufacture geophysical instruments. Also quartered in the building will be Lovelace Manufacturing Co., manufacturers of trucks and heavy equipment for geophysical units, headed by Marion Lovelace as general manager; and Continental Geophysical Co., Oppie Dimmick, general manager, which offers seismograph service on a contract basis.

J. C. Ballagh Elected President Of Patterson-Ballagh

Patterson - Ballagh Corp., Los Angeles, Calif., announces the appointment of J. C. Ballagh as president. Jack Ballagh is well-known throughout the oil world as a pioneer of the rubber drill pipe and casing protector, and also for his active development of many rubber oil-field specialties during the past 18 years. He will continue in charge of sales promotion and development which he has directed since the company's inception in 1927.

Max Miller Sales Manager Of Duraloy Co.

Duraloy Co., Scottdale, Pa., announces the appointment of Max Miller of Detroit as sales manager. He was formerly with Duraloy's representative, F. B. Cornell and associates, in a sales engineering capacity.

Bloom Made Security Division Manager

Security Engineering Co., Inc., Whittier, Calif., announces appointment of D. F. "Duke" Bloom as Craig, Colo., division manager. He brings to his new position 16 years of oil-field experience. His past activities have been in the Gulf Coast, Oklahoma, New Mexico, California and Rocky Mountains.

Fisher Honored by Company

Ed H. Fisher, district manager of Mid-Continent and Gulf Coast area for Pacific Wire Rope Co., has just been awarded a pin marking his thirtieth year of service with this company. He has been in the Houston area since he first opened a branch office in 1938, interrupted by service in the U. S. Coast Guard Reserves. Ed is also noted as a golfer and organist.

Koenig Heads Sales for Tagliabue

A. G. Koenig has been named general sales manager of the C. J. Tagliabue Instrument Division of Portable Products Corp., Brooklyn., where he succeeds E. D. Wacker, who had been previously appointed general manager. Koenig has been with Tagliabue since 1928 when he was made southwestern manager with headquarters in Dallas.

Wilson Supply Opens Branch

Columbus, Tex., is the location of the newest branch of Wilson Supply Co. E. P. McDaniel is in charge of the store.

SUMMARY OF FEBRUARY COMPLETIONS*

	Comp.	Oil	Prod.	Gas	Dry	Under 1,000 ft.	1,000-2,500 ft.	2,500-5,000 ft.	5,000-10,000 ft.	Over 10,000 ft.	Total footage	Rigs and drilling
New York	113	56	84	1	†56	0	113	0	0	0	187,019	132
Pennsylvania	242	132	169	6	‡104	21	203	18	0	0	363,030	238
West Virginia	55	2	6	47	6	0	19	35	1	0	161,889	77
Ohio	91	19	408	43	29	15	29	46	1	0	231,415	192
Indiana	23	19	3,003	0	4	0	20	3	0	0	48,091	53
Kentucky	27	13	2,274	7	7	2	18	7	0	0	59,079	38
Illinois	137	96	12,378	0	§41	0	62	75	0	0	348,335	231
Michigan	53	20	3,557	3	36	1	19	33	0	0	134,494	54
Kansas	140	87	44,398	17	36	1	10	120	0	0	447,974	264
Neb., Mo., Iowa	2	1	145	0	1	0	1	1	0	0	5,911	10
Oklahoma	188	104	19,073	25	¶59	14	37	101	36	0	680,955	452
Texas	538	336	110,880	42	160	25	110	177	210	16	2,550,182	956
North	131	81	23,317	0	50	20	57	33	21	0	375,712	195
West Central	30	13	3,535	1	16	0	10	19	1	0	88,474	75
West	119	99	58,788	1	19	3	20	51	41	4	594,880	255
Panhandle	31	13	4,383	14	4	0	4	27	0	0	94,253	78
Eastern	46	22	5,428	12	12	0	2	14	28	2	288,512	131
Upper Gulf Coast	64	34	5,132	4	26	0	2	9	43	10	462,629	82
Lower Gulf Coast	77	53	8,834	7	17	1	1	9	66	0	503,511	93
South	29	16	906	3	10	0	9	14	6	0	101,539	24
South Central	11	5	457	0	6	1	5	1	4	0	43,672	23
Louisiana	94	58	13,556	13	23	2	6	30	36	20	631,967	202
Northern	53	25	6,152	12	16	2	5	28	18	0	246,304	97
Southern	41	33	7,404	1	7	0	1	2	18	20	385,663	105
Arkansas	17	8	495	0	9	1	6	8	2	0	62,467	38
Mississippi	20	13	2,156	0	7	0	0	2	14	4	143,066	49
Ala., Ga., Florida	3	0	0	0	3	1	0	1	1	0	10,444	13
Montana	17	9	686	2	6	2	11	4	0	0	29,991	62
Wyoming	16	7	2,184	0	9	0	3	9	4	0	67,504	59
Colorado	6	4	2,526	0	2	0	0	1	5	0	38,123	45
New Mexico, SE	28	22	7,638	3	3	3	3	12	10	0	117,168	85
California	128	105	30,467	4	19	2	26	67	26	7	550,993	224
Utah	2	1	25	0	1	0	2	0	0	0	2,795	4
Total February	1,940	1,112	256,738	213	615	90	698	759	346	47	6,872,892	3,478
Total January	2,125	1,198	208,577	187	740	78	778	827	403	39	7,259,081	3,805

*Four weeks ending March 2, 1946. Service wells included: †56, ‡104, §1, ¶1.

N. Central Texas

(Continued from page 297)

Knox field each have eight drilling wells; Sivells Bend, six; National field, Wilbarger County, five; Hildreth field and Lupton field, Young County, each four.

NORTH CENTRAL TEXAS WILDCAT FAILURES

Archer County: D. H. Bolin 3 Jno. Purcell, Lot 80, Jefferson CSL Sur., 2 mi. N and 1 mi. E Anarene, dry, TD 1,119 ft.

D. H. Bolin 4 Jno. Purcell, Lot 80, Jefferson CSL Sur., dry, TD 1,183 ft.

E. B. Clark 1 Wm. M. McGregor, H. H. Duff Sur. A-732, 1½ mi. E and ½ mi. N Huff, elev. 989 ft., Ellenburger 5,639 ft., dry, TD 5,703 ft.

S. F. Hutcheson et al 1 A. L. Harris, Lot 60, J. W. Harris Subdiv., 1½ mi. S and 6½ mi. N Archer City, dry, TD 1,404 ft.

S. F. Hutcheson et al 2 Mrs. S. F. Hutcheson, Lot 142, J. W. Harris Subdiv., 3 mi. E Archer City, elev. 991 ft., dry, TD 2,251 ft.

Cooke County: J. W. Baldwin 1 E. A. Stanley, Jno. DeMarcus Sur. A-314, 2½ mi. N and 1½ mi. W Woodbine, elev. 896 ft., dry, TD 2,722 ft.

Leland Fikes 1 C. W. and D. L. Morrow, Lot 5, Cooke CSL Sur., 6 mi. E and 3 mi. S Valley View, Ellenburger 1,747 ft., dry, TD 1,800 ft.

J. W. Hasings 1 Atcheson Est., T. Polk Sur. A-876, 2½ mi. W and ½ mi. N Hood, Ellenburger 2,860 ft., dry, TD 2,925 ft.

Jack County: P. C. Burns 1 L. W. Wright, J. Robbins Sur. A-490, 1 mi. N and W Antelope, elev. 1,057 ft., dry, TD 807 ft.

J. M. Hickey 2 Chas. E. King, 2 mi. N and E Jermyn, elev. 1,117 ft., dry, TD 301 ft.

Knox County: Youngblood & Foree 1 T. J. Cartwright, Sec. 70, Blk. 45, H&TC Sur., 2 mi. E and 1 mi. N Goree, dry, TD 1,844 ft.

Montague County: Bridwell Oil Co. and Bruce Sullivan 1 McCall & Foshee, J. E. M. Williams Sur. A-883, 1½ mi. W and 3 mi. N Montague, elev. 1,046 ft., Caddo 6,104 ft., dry, TD 6,554 ft.

Throckmorton County: S. D. Johnson and Russell Maguire 1 C. W. Buchanan, Sec. 927, TE&L Sur., 3½ mi. N and W Woodson, dry, TD 1,503 ft.

E. W. Whitney 1 C. A. Turner, Sec. 982, TE&L Sur., ½ mi. NW Woodson, elev. 1,225 ft., Palo Pinto 2,085 ft., dry, TD 2,300 ft.

WEST CENTRAL TEXAS

ABILENE.—Fulwiler & Hughes Drilling Co. and Allied Oil Co. 1 Minnie Templeton, Section 8, HT&B Survey, 1½ miles northwest of Silber Valley, pool opener in northwest Coleman County, has been completed for a natural flow exceeding 42 bbl. of pipe-line oil hourly. Production is from 3,457-86 ft. in Gray through a ¾-in. tubing choke. S. B. Roberts 6 O. J. Cooper, Section 29, Block 15, T&P Survey, gave the Cooper-Roberts pool of Jones County a new pay when it flowed 237 bbl. of 37°-gravity oil in 24 hours from Gunsight lime. The section had been treated with 1,000 gal. of acid through 40 casing perforations from 2,214-30 ft.

Jones County Regular field had three completions this week and Merkel field, Taylor County; Santa Anna field, Coleman County, and Reddin field, Taylor County, each had one. Jones County Regular field had one location. Stephens County Regular field has five drilling wells; Reddin field, Eastland County, Regular field, Palo Pinto County Regular field, and Loving field, Stephens County, each have two.

WEST CENTRAL TEXAS SUCCESSFUL WILDCAT

Palo Pinto County: New oil pool—Ashland Oil & Refining Co. 1-A Lee, Sec. 1744, TE&L Sur., 3 mi. NW Graford, elev. 1,296 ft., pumped 73 bbl. day, perf. 5,040-50 ft. Ellenburger, gravitly 40°, TD 5,050 ft.

WEST CENTRAL TEXAS WILDCAT FAILURES

Callahan County: Norman D. Fitzgerald 1 John R. Kennard, Sec. 8, SPRR Sur., 5¼ mi. N Clyde, elev. 2,021 ft., dry, TD 1,957 ft.

Coleman County: Elgin Sheilds 1 Geo. M. Johnson, S. Cadille Sur. No. 72, ½ mi. N Santa Anna, elev. 1,745 ft., Ellenburger 2,965 ft., dry, TD 3,000 ft.

Palo Pinto County: Edgar T. Hart 1 Mrs. W. J. Mallory, Sec. 37, Blk. 4, T&P Sur., 3½ mi. SW Brad, elev. 1,381 ft., Ellenburger 4,719 ft., dry, TD 4,919 ft.

Shackelford County: Eltex, Ltd., 1-B Merrick, Sec. 16, Blk. 12, T&P Sur., 10 mi. SW Albany, elev. 1,916 ft., Ellenburger 5,133 ft., dry, TD 5,315 ft.

Taylor County: R. H. Roark and L. F. Hooker 1 L. N. Brown, Jose Gabo Sur. No. 128, 1½ mi. NW Tye, elev. 1,746 ft., Swastika 2,705 ft. ,dry, TD 2,775 ft.

Coke County: J. W. Sorrels 1 J. R. Mimms, Sec. 300, Blk. 2, H&TC Sur., 12 mi. N Water Valley, elev. 2,561 ft., Cisco 4,420 ft., dry, TD 7,002 ft.

Crane County: Humble 2 Nellie M. Tucker et al, Sec. 23, Blk. 1, H&TC Sur., 1½ mi. NW McKee, elev. 2,421 ft., Waddell 5,700 ft., Ellenburger 6,040 ft., dry, TD 6,145 ft.

Crockett County: Loffland Bros. 1 L. B. Cox, Jr., Sec. 21, Blk. 2, I&GN Sur., 17 mi. SE Ft. Lancaster, elev. 2,115 ft., dry in San Andres, TD 969 ft.

Dawson County: K. M. Reagan 1 R. E. Speck, Sec. 3, Blk. 34, T-4-N, T&P Sur., 1 mi. S Spraberry field, elev. 2,886 ft., San Andres 3,600 ft., dry, TD 3,957 ft.

Garza County: Honolulu-Devonian 1 H. F. Wheatley et al, 6½ mi. NW Post, elev. 2,936 ft., dry in San Andres, TD 3,631 ft.

Terry County: Texas Gulf Prod. Co. 1 W. H. Collins, Sec. 4, Blk. K, PSL Sur., in extreme NW corner of county, elev. 3,587 ft., San Andres 4,300 ft., dry, TD 5,168 ft.

Illinois Fields

(Continued from page 298)

3,267 ft., Rosiclare 3,319 ft., McClosky 3,350 ft.

Al Cochran 1 McQueen, SW SW NE 6-6s-10e, dry at 3,207 ft., Kincaid 1,902 ft., Golconda 2,611 ft., Barlow 2,724 ft., Cypress sand 2,736 ft., Benoist 2,900 ft., Renault 2,989 ft., Aux Vases sand 3,012 ft., Ste. Genevieve 3,060 ft., Lower O'Hara 3,065 ft., Rosiclare 3,092 ft., McClosky 3,105 ft., St. Louis 3,197 ft.